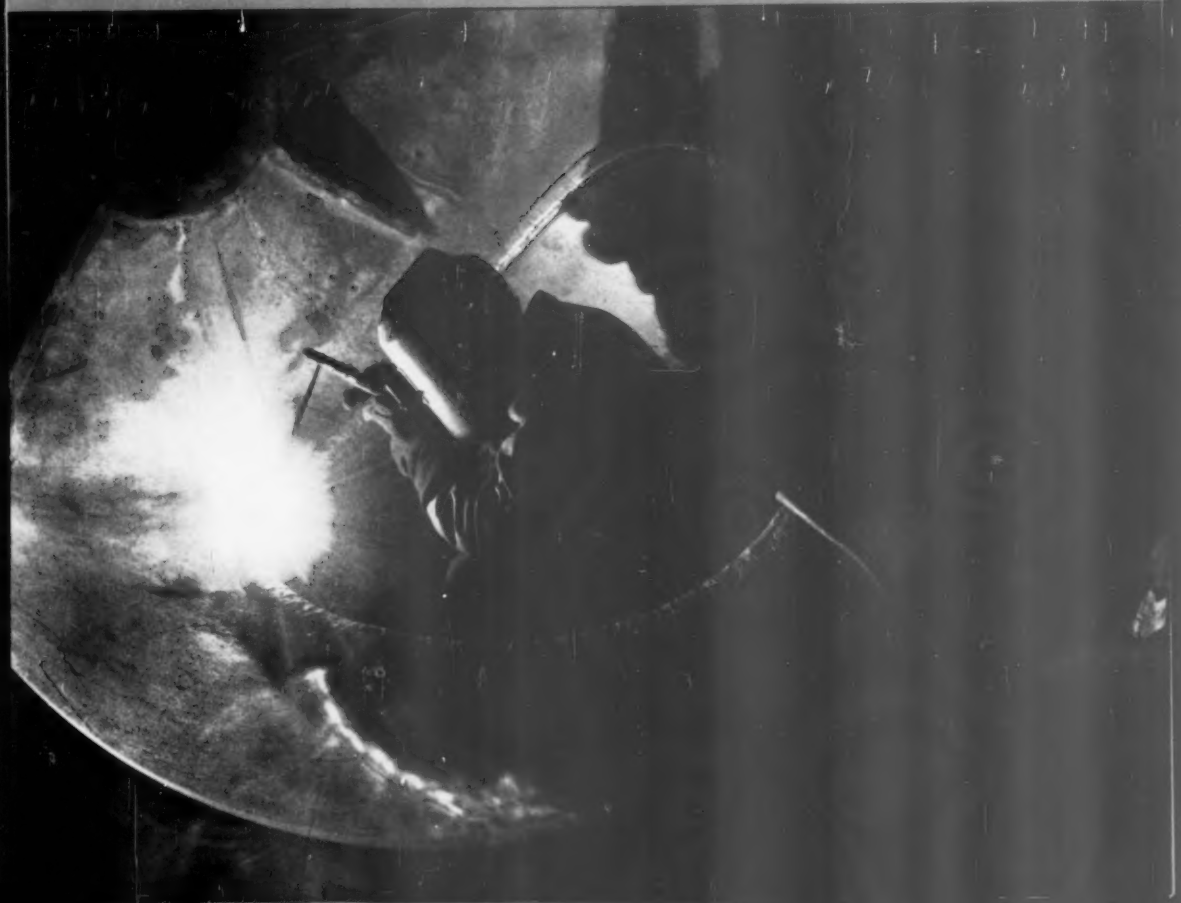
FEBRUARY, 1949

The WELDING JOURNAL

Official Publication of the American Welding Society



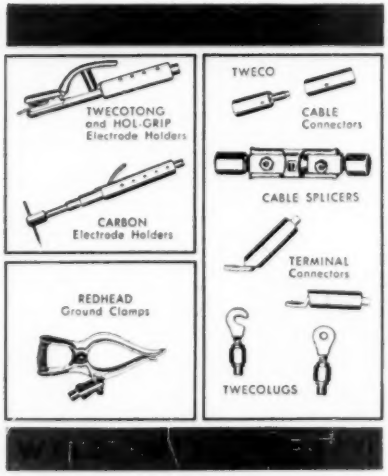
with TWECO CABLE Connections

There are warning signals in welding shops that are sometimes overlooked by busy executives. These signals mean lost arc time that almost invariably results in wasted man-hours, lowered production and less profit from the welding process. Heat belongs in the welding arc and no other place; when it appears elsewhere in the welding circuit, it is a signal that says, "Something is wrong." TWECO cable connections will improve your profit picture. Write for our "Causes and Cures" bulletin on this problem.

2 HUSKY MEMBERS of a sturdy welding family

TWECO stands guard over welding profits

A welding circuit is a pipeline for electric current; it can no more operate efficiently with poor connections than your garden hose at home. Poor connections are a menace to production and profits. If you "Weld with Tweco" you operate at maximum efficiency from the ground to the holder.



It is important that the holder be cool running to avoid blistered operator hands and lost man-hours — TWECOTONG is the answer. There is a TWECOTONG for every job. Four models give a range of sizes to fit the rod and amperage needed. Unnecessary operator fatigue is avoided if you "Job-select" your holder from the Twecotong line. Remember, too, that TWECOTONG'S tough fiberglas insulation is quickly replaceable when arc-charring or natural wearout occurs. Long lasting Super-Mel tip insulation is available at small extra cost where heats are extreme and service is severe. Switch to TWECOTONG for increased welding efficiency.

Model A-38	Model A-14	Model A-316	Model A-532
500 AMPS for 3/8-3/32" rod	300 AMPS for 1/4-1/16" rod	250 AMPS for 3/16-1/16" rod	200 AMPS for 5/32-1/16" rod
$6.50	**$5.00**	**$4.75**	**$4.50**

Prices slightly higher with heavy duty "SUPER-MEL" insulation

It is important to have a solid ground connection that is quickly removable and easily attached again to the work. INSIST on Tweco Redhead Ground Clamps for this purpose. TWECO Redhead Ground Clamps have powerful jaw grip for positive contact, easy-on cable clamps, welded jaw shunts in the larger sizes, insulated springs and high copper alloy construction. A size for every work requirement.

Redhead Model	*Amp. Capacity*	*Cable Capacity*	*Price*
Midget	125 Ampere	No. 6, 4, 2	$1.50
Jr.	300 Ampere	4, 2, 1, 1/0	3.00
Sr.	500 Ampere	1/0 thru 4/0	4.50

Write for Quantity prices. They save you 10 to 27%

Write for Twecolog #7 giving data and prices on the complete TWECO line of electrode holders, ground clamps and cable connections for electric welding.

Tweco PRODUCTS COMPANY

MANUFACTURERS OF ELECTRODE HOLDERS • GROUND CLAMPS • CABLE CONNECTIONS FOR ELECTRIC WELDING

ENGLISH AT IDA • WICHITA 1, KANSAS

YOUR TWECO DISTRIBUTOR CAN SUPPLY YOU

Whether **AC** or **DC** there's EXTRA PROFIT for you with **HOBART simplified ARC WELDERS**

HOBART D.C. electric welder

With Hobart Simplified Arc Welders you get profits that are not mere claims but actual facts—facts that you can prove to yourself by actual test.

An actual test will bring out facts that are immediately apparent, such as cooler operation, extra capacity, easier arc control, and time-saving exclusive features—which make it easier for your operator to do more welding per day with better penetration, with fewer rejects, and with less effort to them.

If you are not using Hobart Welders on your production, construction or maintenance work, it's time you made an investigation of these money-saving, profit-making welders. An investigation costs you nothing—in fact, we're anxious to show you how Hobart Simplified Welders can help you in these days when higher production costs and lower profits are a real problem. Just mail the coupon for complete details—no obligation.

HOBART A.C. industrial welder

HOBART BROTHERS COMPANY

BOX WJ-29, TROY, OHIO

"One of the World's Largest Builders of Arc Welders"

HOBART ELECTRODES

A complete line for every welding purpose, made by Hobart in their modern plants.

HOBART

simplified arc welders

Enroll now!

Special "brush-up" courses

A modern school, teaching new welding techniques, both arc and gas. A "brush-up" course brings you up-to-date on everything that's new. Low in cost, a non-profit school. Write for details.

The HOBART SCHOOL of welding

Practical Design for Arc Welding

Gives you in design form hundreds of ideas on how to use welding with profit. **$3.50** Per. Vol.

Set of 3 different books $10.00

Fill out and MAIL today!

HOBART BROTHERS COMPANY, Box WJ-29, Troy, Ohio

Am interested in extra profit through use of Hobart Welders. Send complete information and catalog on

☐ A.C. WELDERS ☐ D.C. WELDERS

Also send information on ☐ WELDING SCHOOL

☐ HOBART ELECTRODES

FREE!

☐ Hobart "Guide to Better Welding"

Name _____

Firm _____

Address _____

CONSULT WITH
RESISTANCE
WELDING ELECTRODE
HEADQUARTERS

It takes all three...
SKILL, EXPERIENCE AND TOOLS
...to make the forgings you need

It takes years of training to acquire the skill to properly forge one of these large seam welding wheels.

MALLORY CAN SUPPLY YOU!

If you need seam welding wheels, rods, rectangles, die blocks, bearings, bushings, shafts, spindles, or special shapes . . . made of hardenable copper alloys which are specifically designed for the job . . . you want to see Mallory!

Mallory metals and designs are the result of years of research and engineering skill in the Resistance Welding field. Mallory has perfected methods of hot forging, heat treating and cold forging that give Mallory forged alloys the maximum uniformity in density and hardness.

Whatever your Resistance Welding problem, Mallory can supply your needs from one of these forged alloys . . . all have special characteristics for efficient operation on special jobs . . . Mallory 3*, Elkaloy A*, Mallory 53-B, Mallory 73, Mallory 100.

SEND YOUR SPECIAL FORGING PROBLEMS TO MALLORY, AND BE SURE!

In Canada, made and sold by Johnson, Matthey & Mallory, Ltd., 110 Industry St., Toronto 15, Ontario.

Resistance Welding Tips, Holders, Dies, Rod and Bars, Castings, Forgings

P. R. MALLORY & CO. Inc.

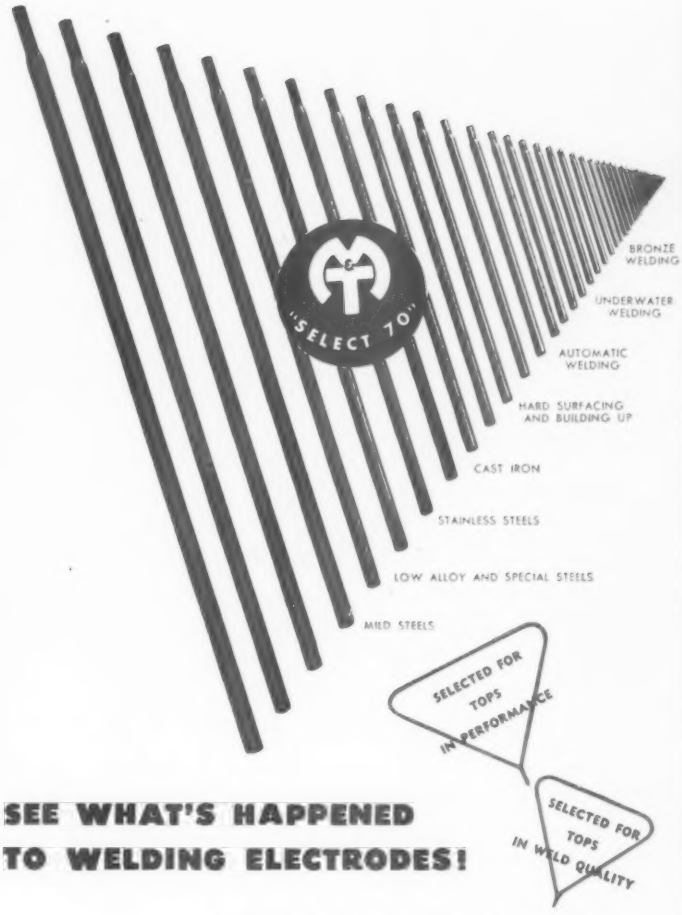
MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SERVING INDUSTRY WITH

Capacitors — Rectifiers
Contacts — Switches
Controls — Vibrators
Power Supplies
Resistance Welding Materials

*Reg. U. S. Pat. Off.



SEE WHAT'S HAPPENED TO WELDING ELECTRODES!

Time was when you had to tackle almost every arc welding job with just one electrode. Now electrode types come by the score.

Nearly 20 years ago M & T started something with its Murex "hot rod" for downhand welding — one of the first electrodes engineered to do a specific job and do it better.

Today M & T is well out in front with the "SELECT 70."

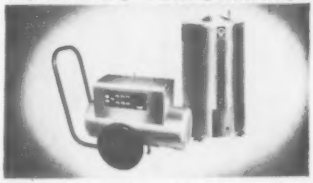
Yes, now there are 70 types of electrodes in the M & T line — each one selected from a number of designs to give top performance on a particular class of work — each one picked to help you do the best possible job, more speedily, at lower cost.

You need look no further than M & T's "SELECT 70" for easy selection of the right electrode for any application. Write today for your brief but comprehensive catalog.

METAL & THERMIT CORPORATION

120 Broadway • New York 5, N. Y.

NEW ARC WELDERS BOOST AC and DC PERFORMANCE



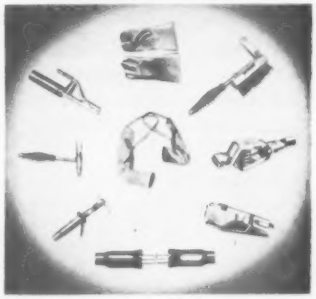
FASTER welding, better quality welds, lower power costs, and simplified maintenance are furnished by a new line of AC and DC arc welders introduced by Metal and Thermit Corporation.

Built-in capacitors for high power factor, wide current range for full rated output, and, fingertip, stepless current control for precise current setting are featured in the AC units. Available in 150 to 500 amp. models for manual arc welding, additional models for inert arc and automatic welding.

Full capacity, rugged duty DC arc welders are compact, light in weight—half the size and half the weight of older types—and are equipped with simplified current control, automatic electrode selector. Furnished in 150 to 400 amp. sets—motor driven, engine driven or belt drive.

Descriptive folder gives full particulars. Address Metal and Thermit Corporation, 120 Broadway, New York 5, N. Y.

ACCESSORY DIVIDENDS DECLARED



UNDERSCORING the importance of proper accessories to top welding performance, more and more fabricators are taking pains with selection of accessories. Speedier, lower cost, safer and improved welding are assured when such items as helmets, shields, holders, connectors, cleaning tools and protective clothing are carefully selected. And more and more fabricators—sold on M & T electrode and arc welder performance — are specifying the M & T line of "accessories to the perfect weld." For descriptive literature, address Metal and Thermit Corporation, 120 Broadway, New York 5, N. Y.

volume 28 FEBRUARY, 1949 number 2

the WELDING JOURNAL

published for the advancement of the science and art of welding by the

AMERICAN WELDING SOCIETY

Editor

W. SPRARAGEN

OFFICERS

G. N. Sieger	*President*
O. B. J. Fraser	*1st Vice-President*
Harry W. Pierce	*2nd Vice-President*
R. S. Donald	*Treasurer*
J. G. Magrath	*Executive Secretary*
M. M. Kelly	*Secretary and Asst. Treas.*
Simon A. Greenberg	*Technical Secretary and Handbook Editor*

DISTRICT VICE-PRESIDENTS

District #1—New York and New England
George M. Trefts, III

District #2—Mid-Eastern
Gerard E. Claussen

District #3—Southern
R. E. Lorentz, Jr.

District #4—Central
Fred L. Plummer

District #5—Mid-Western
J. R. Wirt

District #6—Mid-Southern
Ray L. Townsend

District #7—Western
Gilbert S. Schaller

CONTENTS

technical papers, items and reports

Riveted Vs. Welded Ship Structure, by E. M. MacCutcheon 111
Discussion by L. P. Brown 118
Discussion by Wendell P. Roop 119
Discussion by David Arnott 120
Discussion by John Vasta 121
Author's Closure 121
Fabrication of Structural Steel Sections, by J. M. Tippett 123
Practical Aspects of Inert-Gas Welding, by H. A. Huff, Jr. and A. N. Kugler 128
Current Welding Literature 140
Welding Alloy Steels for High-Temperature Service, by M. E. Holmberg 141
Materials Joined by New Cold-Welding Process, by A. B. Sowter 149
Hard Surfacing of Cast-Steel Propeller Blades, by K. B. Young, H. J. Nichols and M. J. Nolan 153

practical welder and designer

How to Design Wheels 158
Utility Problems in Supplying Power for Resistance Welding, by H. B. Wood 160
Copper and Its Alloys 161
Designing for Welding—Part II, by Wallace A. Stanley 162
Handy Welded Steering Hitch Easy to Make 163
Economical Service for Resistance Welders, by E. F. Dissmeyer 163
Spirit Level Positions Carriage for Welding Girth Seams 164

society and related events

Society News 165
INDEX TO ADVERTISERS 166
News of the Industry 170
Personnel 180
New Literature 184
New Products 190
Section Activities 198
List of New Members 205
Abstracts of Current Welding Patents 206
Employment Service Bulletin 207

welding research supplement

The Work of the Ship Structure Committee 49-s
Fracture Characteristics of Ship Plate in Certain Small-Scale Tests, by E. P. Klier, F. C. Wagner and M. Gensamer 50-s
Axial Tension Impact Tests of Structural Steels, by W. H. Bruckner and N. M. Newmark 67-s
Discussion by Wendell P. Roop 80-s
Discussion by George Irwin and J. A. Kies 82-s
Discussion by E. P. Klier 83-s
Discussion by I. R. Kramer 84-s
Discussion by A. B. Bagsar 84-s
Authors' Closure 87-s

cover: Facing large cast iron valve with Monel electrodes over a Ni-Rod base. Courtesy The International Nickel Company, Inc.

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices, 33 West 39th St., New York 18, N. Y. Advertising office, 400 Madison Avenue, New York 17, N. Y., Telephone: Plaza 3-4466. Subscriptions $5.00 per year in United States and possessions; foreign countries $7.00. Single copies, non-members $.75; special issue October $1.00; members 50 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton, Pa., under the act of March 3, 1879.

Copyright 1949, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided proper credit is given.

Welding heavy-duty grader wheels by the UNIONMELT *welding process.*

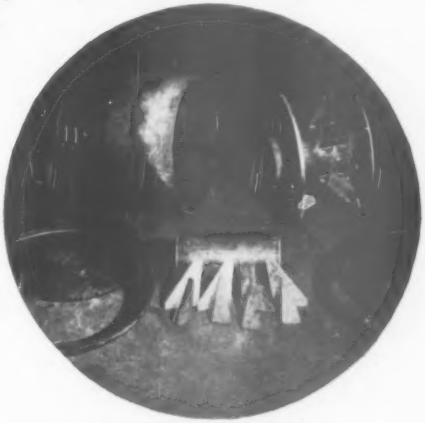
Swing into Mass Production

with the UNIONMELT Welding Process . . .

It is automatic—fast—easy—Makes top quality welds—Gives maximum production with a minimum of space.

The extremely high currents that can be used with the UNIONMELT welding process result in deep penetration and high welding speed. The weld metal is clean, uniform, and dense; and requires no chipping or peening to finish it. The UNIONMELT process of welding electrically beneath a protective layer of granulated welding composition is ideally suited to repetitive welding. Material from 16 gage to 1½ inches in thickness can be welded in a single pass with this process. By using the proper UNIONMELT composition and welding rod, alloy steels and even non-ferrous alloys can be welded as easily as the regular grades of mild steel.

There are many LINDE methods for joining, forming, cutting, and treating metals. LINDE engineering service is always on call to help customers with production, construction, and maintenance jobs. Just call the nearest LINDE office.



Here are the parts that make up a heavy-duty wheel.

Here are the completed wheels—ready to roll.

Linde
Trade-Mark

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
General Office: New York, N. Y. UCC Offices in Principal Cities
In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto
The words "Linde," and "Unionmelt" are registered trade-marks of The Linde Air Products Company

Introducing

4 ENTIRELY NEW FLUXES *by* VICTOR

Developed to Give You Cleaner, Stronger Welds at Lower Cost

These 4 new fluxes—One of the greatest developments in fluxes in 20 years—are the result of intensive engineering research based on Victor's 40 years of practical welding experience. Try them; see for yourself how to get *more brazing per pound* with these 4 new fluxes.

Victor's New Fluxes Fulfill All these Important Requirements

- Effectively clean parent and filler metal
- Cling to heated rod when dipped into flux
- Do not blow off rod
- Contain no useless ingredients
- Leave finished braze clean
- Contain no toxic ingredients
- "Tin" burned spots in cast iron brazing
- Do not encourage cooling of cast iron welds

Get your supply from your welding dealer **TODAY**

DEALER INFORMATION UPON REQUEST

NO. 3

Victor No. 3 Flux for brazing brass and bronze, steel, clean cast and malleable iron. Leaves clean, natural finish.

NO. 5

Victor No. 5 Flux for moderate heat brazing of cast and malleable iron. Excellent for dirty castings.

NO. 7

Victor No. 7 Flux for high heat brazing of cast and malleable iron where base metal gets exceptionally hot.

NO. 9

Victor No. 9 Flux for cast iron welding. Fast and effective. Will not cake when container is subjected to moderately high heat.

VICTOR
FOR BETTER WELDING

VICTOR EQUIPMENT COMPANY

844 FOLSOM STREET • SAN FRANCISCO 7, CALIFORNIA

3821 SANTA FE AVE., LOS ANGELES 11, CALIF. • 1312 W. LAKE ST., CHICAGO 7, ILL.

The WELDING JOURNAL

volume 28 February 1949 number 2

Riveted Vs. Welded Ship Structure

Riveting vs. welding in ship construction with regard to the incidence of cracks in ships. Ability of the structure to resist the starting of cracks compared

by E. M. MacCutcheon

Abstract

Investigations initiated in connection with the cracking of merchant ships during World War II have uncovered new evidence bearing on the relative incidence of cracks occurring in ship structures fabricated by riveting and by welding. These new findings are critically reviewed along with certain widely accepted viewpoints. Available data are compared to test the validity of evidence bearing on the incidence of cracks. It is concluded that there is no evidence indicating that either riveted or welded structure is more susceptible to the inception of cracks.

INTRODUCTION

RIVETING had been the principal method of structural fabrication for many years before welding became a serious competitor. The introduction of welding was hampered by the natural inertia which accompanies the replacement of a universally accepted engineering method. Furthermore, it was beset by technical difficulties which made it a good target for criticism and the brunt of many unfair comparisons. The comparative merit of riveting and welding was the subject of prolonged speculation and controversy. Repetition and conjecture wore the subject threadbare. Actually there was such a dearth of facts that many of the original arguments remained unsettled.

Early discussions on this subject were replete with wishful thinking. This was largely engendered by the natural resistance to the birth of a new industry. Welding has now established its place in structural fabrication, and the causes for rancor have been mellowed by time. A reopening of this question should be possible with complete freedom from mercenary bias.

The epidemic of structural failures in merchant vessels has revived many of the original contentions associated with this dormant controversy. In commencing their recent survey of the structural-failure problem, the naval architects were confronted by the same provoking lack of factual data which had spirited much of the earlier debates and which befogged the true nature of the problem. Early recognition of the shortage of facts encouraged the establishment of the broad statistical studies and research investigations which are now bearing fruit in our technical literature. Among the findings of these studies,[1,2] are many facts relating to the question of riveted vs. welded structure.

The time has come for a reappraisal of the subject. The study of the problem is fraught with practical complications. It is difficult to separate the influencing variables and study them one at a time even in the research laboratory. Much of the apparent contradiction of earlier tests results from a failure to recognize the importance of certain influential parameters. Recent studies have emphasized notch sensitivity. This means that the toughness of the steel and the temperature of the test are important to the results. Early tests seldom included control or even recognition of these effects. A recent tensile test on a riveted butt joint with a nominal efficiency of 85% resulted in a fracture in the base plate starting at a sheared edge and completely avoiding the riveted joint. This test was made at $-20°$ F. It is clear that the notch sensitivity is important to riveted as well as to welded structure, but the relative influence may not be the same.

A careful statement of the problem is essential to an evaluation of the new evidence bearing on the relative merits of fabrication by riveting and welding. There are many bases for making the comparison between riveting and welding, for example, construction costs, maintenance costs, weight economy and structural performance. The following discussion concerns the structural performance only.

The ultimate merit of a structure depends on its

E. M. MacCutcheon is a Naval Architect at the David Taylor Model Basin, U.S.N., Washington, D. C.

This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948. The opinions expressed are those of the author and are not necessarily those of the Navy Dept. or of the Ship Structure Committee.

ability to resist failure. In a ship's hull, failure may be of two types, a crack or a buckle. The structural performance of the hull may then be measured by three yardsticks: (1) Its ability to prevent the formation of buckles, (2) its ability to resist the propagation of cracks and (3) its ability to resist the starting of cracks.

It has been amply demonstrated that the riveted structure, with faying flanges and stiffening overlaps will present more resistance to compressive loading than its welded counterpart when functioning in a ship's hull. Likewise the evidence, accumulated during the last few years, firmly establishes the crack stopping capabilities of a riveted seam. By providing a sufficient number of carefully located riveted barriers, it would be possible to build a welded ship which is equal to a riveted ship, in so far as resisting the propagation of cracks is concerned. The relative merit of such a structure, with regard to cracking, would then depend entirely on the likelihood of crack inception. This is the third yardstick of structural performance and it is intended to limit the remainder of this paper to discussion of this third yardstick, i.e., the ability of the structure to resist the starting of cracks.

It was the intention of the author to assemble some of the more recent data bearing on the incidence of cracking and to test their validity in this paper. By accumulating all the resulting findings in a logical array it was supposed that new facts would make themselves evident. The course of this paper was set toward a noble destination; but the reader is hereby warned to curb his expectations lest the following discussion appear anticlimactic. Practically all of the findings are negative. Negative findings are important, however, even though they may be much less interesting than positive results. For the case in question, the negative findings take on additional importance because they contradict widely voiced opinions upon which engineering judgments are based every day. The opportunity to contend such viewpoints supplied the incentive to complete the discussion which follows.

Evidence bearing on the resistance of the structure to the starting of cracks can be more easily handled if it is divided into two groups; first, direct evidence statistically relating the occurrence of cracking with the method of fabrication (riveting or welding), and second, indirect evidence. Indirect evidence includes data by which the method of fabrication can be shown to influence factors which, in turn, influence the cracking. Such factors must, of course, include only those which are known to have a real influence on the incidence of cracking.

The voluminous study of structural failures during World War II provided ample opportunity to survey the fractures in welded ships and become familiar with their detailed characteristics. A similarly detailed study has been accomplished on at least one riveted ship, the *Oakey L. Alexander*.[3] This latter survey shows that features of the failure were similar to those observed on the welded ships. The similarity of the fractures is important. If the fractures were not similar, it is probable that their occurrence would be encouraged by a different set of influencing factors. The fact that the fractures are similar admits the ready and direct comparison of data bearing on the influencing factors.

The important factors, governing the incidence of cracking, are type of steel, state of stress (constraint), temperature and magnitude or rate of loading applied to the critical region. Indirect evidence will hardly ever be quantitative in nature. The causes are twice removed from the effects, and a quantitative relation between the influencing parameters and the likelihood of cracking has been established in only a few special cases.

PRESENTATION OF EVIDENCE RELATIVE TO THE INCIDENCE OF CRACKING

For ships' hulls constructed by riveting and by welding the following direct evidence has been submitted as indicating superiority of riveting with regard to the incidence of cracking: (1) The relative number of ships which broke in two when hit by torpedoes, (2) the reputedly higher incidence of fracture in the welded ships and (3) the comparatively few serious failures occurring on the Bethlehem Fairfield Liberty Ships.*

As direct evidence indicating superiority of welding the following may be cited: The higher incidence of cracking in the ships fitted with riveted crack arrestors.

Indirect evidence was stated, above, to include data bearing on type of material, degree of constraint, temperature and the magnitude or rate of applied loading. Obviously the method of fabrication cannot be expected to influence the type of material or the temperature. The applied loading refers to the magnitude of the stress values in the parts of the structure where trouble is likely. Locked-in stresses are, therefore, considered a part of the loading. Of the factors controlling fracture, both loading and constraint can be influenced by the method of fabrication (riveting or welding).

Welding involves cavities, underbead cracking, etc Riveting involves sheared edges and rivet holes. Few qualitative and no quantitative statistical data have been obtained, bearing on the relative danger from notches typical of the two types of fabrication. This means that there is no indirect evidence bearing on the degree of constraint. Likewise, there have been no comparative tests on the two types of structure which involve rate of loading. Hence, all the indirect factors except the magnitude of load, are eliminated from consideration because of the lack of information. Some data have been obtained on the effect of riveting and welding on the magnitude of the stress, i.e., the loading in critical regions, and this is the only indirect evidence which it is possible to assemble.

Indirect evidence indicating lower stress values in the riveted structure includes the following: (1) Numer-

* The Bethlehem Fairfield Liberty Ships were the only ones with riveted shell seams.

ous reports of higher flexibility* and lower stresses in the riveted ships, (2) the construction stresses locked in the decks of the ships with riveted gunwales and a riveted deck seam are reported to be compressive and higher than those recorded in corresponding locations of ships with welded gunwales and (3) tests of riveted joints indicate a nonelastic behavior at high stresses.

Some of the indirect evidence may also support the possibility that no difference results from the type of structure. Included are the following: (1) An examination of cap welds; spanning riveted seams and in way of welded butts failed to reveal any cracks and (2) as a result of their tests on the two sister tankers, the *Neverita* (welded) and the *Newcombia* (riveted), the British report no substantial difference in the behavior of the two structures, with regard to deflection of the hull.

DISCUSSION OF DIRECT EVIDENCE

Records are available for study of 331 riveted or welded ships which were torpedoed during World War II. Of these vessels 48 broke in two. For the ships constructed by riveting, those breaking in two made up 14% of the total number struck by torpedoes. For the welded ships, the percentage was 18. The number of ships involved in this study is nowhere near sufficient for a valid statistical conclusion. But, even if the sample were adequate the results would not prove that the incidence of cracking is lower in the riveted ships because the riveted seams prevented the ships from breaking in two in many instances, of which several reported cases can be cited as examples. The evidence is, therefore, invalid and must be discarded.

Riveted ships have suffered structural distress. The famous liners *Leviathan* and *Majestic* cracked their main decks, and several riveted tankers have broken in two. No longer ago than March 1947, the *Oakey L. Alexander*, a riveted collier 31 years old, broke in two, off the coast of Maine. For four years during World War II a complete central record of structural failures was maintained for all U. S. ships. Great numbers of nearly identical ships were in service as a result of the Maritime Commission construction program. Comparison of the fracture records with the accumulated service data permitted a reasonably accurate statistical study to be made. The large groups of ships, however, were made up almost entirely of Liberty Ships, T2 tankers, Victory ships and other new ships which were practically all welded. The only mass production program of riveted ships occurred during World War I. Few of these ships were still in operation during the period of the structural-failure study described above.

With the exception of the outstanding examples of failure, the structural-performance records of the riveted ships are hopelessly scattered or lost. Many a cracked plate was replaced as a part of the voyage repair of a riveted ship, but we shall never know how many. Here again no conclusion can be drawn as to the relative performance of the two types of fabrication with regard to the incidence of cracks.

The Bethlehem Fairfield Liberty ships had riveted shell seams; the other Liberty ships did not. This inspired the operational managers of the War Shipping Adm. to assign these ships to routes where inclement weather prevailed. The service record of ships built by this yard was above average in so far as the incidence of cracks was concerned. However, it cannot be concluded that this superiority was directly attributable to the presence of the riveted seams. Other factors may have assisted to account for part, or all, of the difference.

The records show that the training and supervision of labor as well as the other fabrication techniques employed in the Bethlehem Fairfield Yard were little different from those in other yards. Considering the leveling effect of the thousands of men working on these jobs all personality factors are barred. It must be concluded that workmanship could not have accounted for the superiority of the Bethlehem Fairfield ships. On the other hand, steel has been proved to be an important factor in the fracture problem. The steel for the Liberty Ships was generally allocated on a nationwide basis, but it has been found that about two-thirds of the steel for the Bethlehem Fairfield ships came from the nearby Bethlehem-Sparrows Point rolling mill. It is not known whether this steel was better than average, but its preponderant use unsettles direct reasoning.

The degree of superiority of these ships over other Liberty ships is not overwhelming. They incurred only 15% as many serious failures as the average, but the percentage is about 55 when all magnitudes of damage are included. One other yard which built more all-welded vessels actually had a better record for all classes of failures. After considering all these factors it must be admitted that the record of the Bethlehem Fairfield ships does not determine, beyond dispute, the beneficial attributes of riveting the side shell as a crack inhibitor.

Evidence which appears to support superiority on the part of the welded structure, must be similarly evaluated. One group of Liberty ships, all of which were completed before Feb. 1, 1943, was submitted to a statistical appraisal. This group included 667 vessels on which the construction practices were of about the same quality and on which the design details were practically identical. There was only one season, i.e., the winter of 1944–45, during which this group of ships was reasonably well-divided between those fitted with riveted crack arrestors and those which had not yet been altered to incorporate the arrestors. During this winter season the ships without crack arresters accumulated 1620 ship-months of service time and incurred 10 fractures. The ships with crack arrestors accumulated 847 ship-months of service time and incurred 16 fractures. The incidence of fracture for the ships without crack

* The term "flexibility" is used, in this paper, to signify the relative deflection of the hull structure as compared with strictly elastic action with no buckling. By this definition flexibility becomes a manifestation of rivet slip, of the eccentricity in riveted overlaps and of other buckling. This is believed to be the most common usage of the term.

arrestors was 0.006 fractures per ship-month, and the incidence for ships fitted with crack arrestors was 0.019 fractures per ship-month. This is a small sample of data for a statistical comparison. In addition, it is known that the service conditions for the two groups of ships were not equal. The assignment of operating routes depended on the availability of ships which had been fitted with crack arrestors. Such ships were always assigned to routes where severe weather conditions were anticipated. When this fact is considered, it is necessary to reject the study of ships with crack arrestors as evidence bearing on the risk of incurring cracks in riveted or welded structures.

DISCUSSION OF INDIRECT EVIDENCE

During World War II there was a widespread impression in marine circles that a riveted ship was less likely to incur cracks. It has already been pointed out that there are no statistical data confirmining such a rumor. The rumor in question did not originate from the performance of the Bethlehem Fairfield Liberty Ships for the simple reason that, when the rumor was at its height, the Bethlehem Fairfield Yard was just getting into production and the apparently good service record of the ships had not yet been established. Actually, it is believed that this confidence in the riveted structure stemmed from its crack-stopping ability rather than from its ability to eliminate the starting of cracks. The ship masters developed their individual hypotheses for the rumored superiority of the riveted ships. The most widespread explanation was "flexibility." Reports of additional flexibility in riveted hulls were numerous. Efforts have been made to locate a factual basis for these reports, but none has been found. No actual measurements have been taken except in the formal structural studies which are already receiving much attention. It is believed that the flexibility reports must be disregarded because they completely lack factual support.

It has been reported that the locked-in stresses in a fore-and-aft direction in the decks of welded ships are generally compressive in nature, with values ranging from 8800 psi. in tension to 16,600 psi. in compression. One study showed that vessels with riveted gunwale angles and a riveted deck seam, with a seam strap, had higher compressive stresses than a similar group with welded gunwales. There are no test data to dispute this finding. It should be studied from a statistical viewpoint, however. Only six ships with welded decks and five with riveted gunwales and deck seams are included in this study. The difference in stresses, about 4000 psi., is small when compared with the scatter of results (10,000 psi.). All the 11 ships included in this comparison had riveted shell seams. On the basis of the same tests, the investigators point out that the results from either the group with the welded gunwale, or those with the riveted gunwale and deck, compare well with two other surveys of locked-in stresses. These other surveys included tests on 23 Liberty ships and 26 Victory ships. The hulls of these ships were all welded except that the Victory ships had riveted gunwales. If it is remembered that all 11 ships in the above-mentioned comparison had riveted side shell seams, this evidence cannot be taken to indicate that the presence of riveting influenced the stress locked in the Liberty-ship decks.

The fact that riveted joints under test manifest slip in the form of nonelastic behavior cannot be disputed. It is true that, with special techniques of riveting, special materials and careful alignment of rivet holes, the extent of this nonelastic performance can be minimized. Such care cannot be expected in the construction of a ship, so the question reduces to one of whether this nonelastic performance exhibits itself in an average structure under the influence of normal operating loads.

Extensometers placed on a riveted deck butt and adjacent seam during the launching of a new heavy cruiser failed to indicate evidence of slip. The stress in the deck reached 16,000 psi. Due to the fact that the riveted butts in a ship's hull are staggered, a certain amount of the longitudinal load is taken by the rivets in the seams between the staggered butts. The proportion of load carried by the seams varies from nearly zero at low loads to as much as 45% when failure is imminent. The longitudinal load in the seams is mainly controlled by the eccentricity of the butts at low loads and rivet slip as the load increases. In the case of the above-mentioned cruiser it is known that the area of riveted cross section in shear in the butts is about equal to the corresponding section of deck plating. Hence, it can be said that the stress on the rivets during this test had a maximum value of 9000 to 15,000 psi. The spread of maximum values is due, of course, to uncertainty of the load on the seams.

Measurements on the destroyers *Preston* and *Bruce*[4] did not include direct measurements of rivet slip, but some of the gages were placed across deck butts. In this test the stress values for which no evidences of slip were recorded were 6000 to 12,000 psi. At higher loadings the elongations were not recoverable and leakage occurred in underwater butts. Slip had certainly occurred. The fact that these ships, two old and one new, showed no slip, until the above-mentioned stress values were reached, is interesting. Laboratory tests of typical ship construction joints confirm these results with reports of slip for values of 6000 to 7000 psi. on the rivets.

Service records show that hundreds of loose rivets must be replaced in a ship which has weathered a particularly heavy storm. This is a common occurrence, and it must be concluded that rivets do slip under severe operational conditions. On the other hand, the tests show that it must take moderate stresses to promote slip (above 6000 psi. on the net section of the rivet).

In ships constructed with welded butts and riveted seams it is common practice to fuse one strake of plating to the next by means of a short fillet weld deposited in way of each welded butt. These welds are usually

about 3 in. long and are commonly known as cap welds. Before an appreciable shear deflection could occur in the riveted seam, it was supposed that such small welds would show evidences of distress, either in the form of yielding or cracks. An examination of these welds on several Liberty ships, which had already seen extensive service, failed to reveal any cracked cap welds. Even when visual inspection was supplemented by magniflux it was not possible to detect cracks. In order to verify this finding a test was made of a large specimen fabricated from 1- and $^3/_4$-in. plating and including typical cap welds in shear. A shear displacement of nearly $^1/_{32}$ in. occurred before the cap weld cracked. If rivet slip occurred in these ships, the magnitude of slip was evidently less than $^1/_{32}$ in.

The remaining indirect evidence comes from the British test program on the *Nevcrita* and *Newcombia*.[5,6,7,8] The report on the *Newcombia*[6] includes a conclusion with regard to the comparison between these two ships which reads as follows: "The stress distribution and longitudinal deflections in the two forms of construction show no major differences." This conclusion should be interpreted in terms of flexibility and slip stress with the greatest caution. The theoretical deflection of the hull resulting from rivet slip depends on the particular hypothesis for rivet slip assumed. In order to demonstrate this, calculations were made on the *Newcombia* in hogged condition to show the amount of hull deflection which could be expected as a result of assuming two separate hypotheses for rivet slip.

Under Hypothesis 1 it is assumed that the stress on each rivet is a definite fraction of the stress, which would have been on the rivet, had no slip occurred. Hence, for any given degree of slip the shear-deflection for the various joints is proportional to the applied stress. Under Hypothesis 2 it is assumed that slip is nonexistent until a certain stress level is reached, in the rivet. It is assumed that the rivet stress cannot increase above this level, hence, further increases in shear deflection occur at a constant maximum stress value. The two hypotheses are shown graphically in Fig. 1.

Figure 2 shows the deflection of the ship's hull corresponding to various amounts of rivet slip for each of the two hypotheses. A careful study of the test results indicates that the deflection of the riveted ship was actually 4 to 7% higher than that of the welded ship.

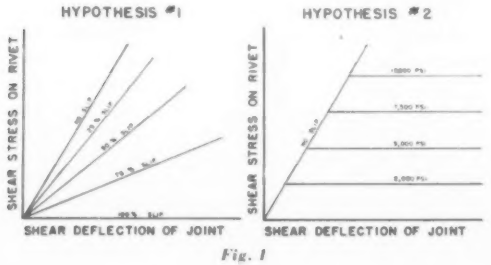


Fig. 1

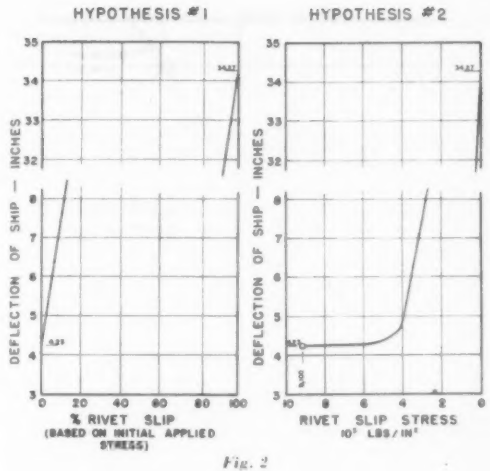


Fig. 2

If Hypothesis 1 is accepted, this additional deflection would correspond to a very small percentage of rivet slip, Fig. 2. On the other hand, if Hypothesis 2 is considered to be the acceptable explanation, a low value of slip stress must be assumed in order to correspond to the slight additional deflection. The slip stress would be only about 5000 psi. for 4% additional deflection.

Probably neither hypothesis is correct, but the true action may lie between these two. If slip occurs, a stress distribution study might reveal a clew as to the proportionate influence of the two hypotheses for rivet-slip stress. This requires a detailed study of the test results with extensive calculations. Work along these lines has been started but is not completed. One fact is clear at this state: The presence of the welded longitudinal bulkheads in the *Newcombia* masks the difference in performance between it and the all welded *Nevcrita*. A greater contrast will undoubtedly result from the comparison between the *Ocean Vulcan* and the *Clan Alpine;* these ships have no longitudinal bulkheads.

The bending loads on the hull of a ship are controlled by the longitudinal distribution of weights and buoyancy and by certain dynamic and form characteristics which govern the ship's reactions in a seaway. None of these factors are influenced by the type of fabrication used in the hull. The internal resisting moment in the hull structure must be in harmony with external conditions at all times. This is an important fact, which is frequently overlooked when glorifying the stress-ameliorating benefits to be expected from rivet slip. Slip in the riveted joints can redistribute the stress in the structure, but the internal bending moment cannot be changed. Figures 3 and 4 show the internal stress distribution amidships necessary to meet the requirements of external loading.* Figure 3 indicates the stress distribution corresponding to Hypothesis 1, which was previously described. Figure 4 shows the distribution

* A hull deflection, in the presence of rivet slip, amounting to 5.21 in. was assumed for the stress calculations. This value was arbitrarily selected in order to display an obvious difference in stress distribution.

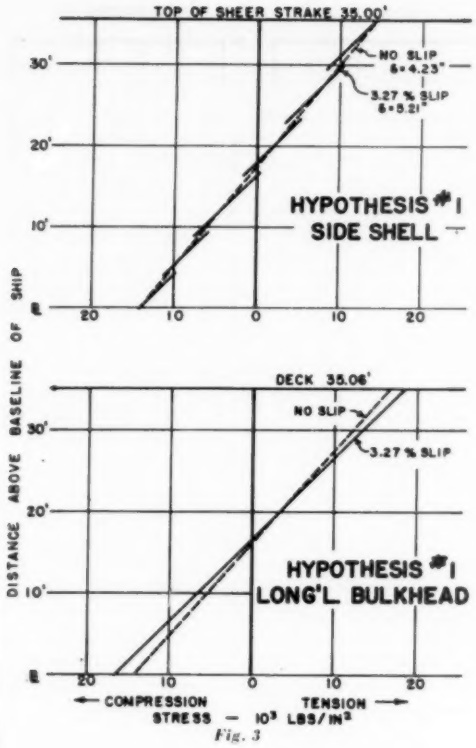


Fig. 3

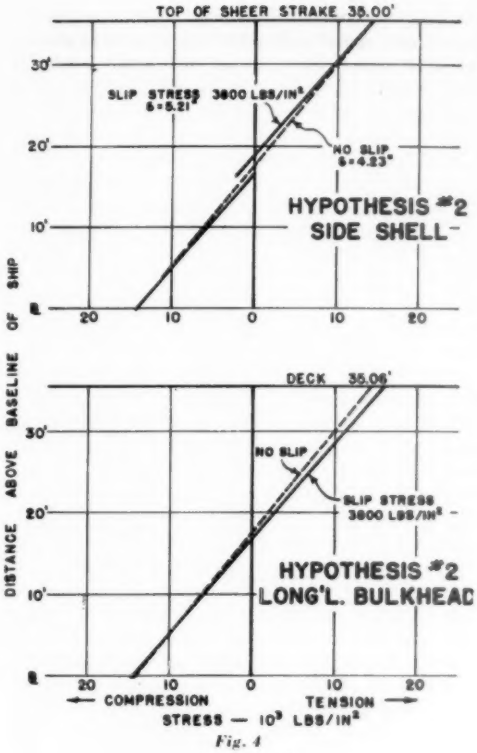


Fig. 4

for Hypothesis 2. Under either hypothesis, it can be seen that, while some portions of the structure incur stress reductions, other portions suffer increases. It is clear that the effects of rivet slip on stress magnitude are more likely to be harmful than to be beneficial because the peak stresses become higher and higher as the structure subdivides into less competent units. This would be particularly serious if the peak stresses happen to occur at critical locations.

GENERAL DISCUSSION

Other suggestions have been proposed regarding the possible influence of riveting and welding on the stress distribution in the ship hull. Riveted joints involving overlaps naturally produce a load-elongation relationship differing from that of a steel plate because of the eccentricity of the joint. The longitudinal seams of a ship always consist of eccentric overlaps of this type. It has been maintained that the presence of these seams is influential in reducing the transverse stresses in the deck and bottom of the ship thereby decreasing the degree of biaxiality and perhaps the incidence of cracks. An examination of the transverse stresses in the deck and bottom of the *Neverita* and *Newcombia* fails to reveal a pronounced difference in magnitude. Although the deck-stress range is less on the *Newcombia* (riveted), the scatter of values seems to have been influenced considerably more by local effects on both ships than by the presence of the riveted seams. These ships are tankers, with longitudinal framing in deck and bottom. The transverse stresses are lower than on transversely framed ships. It is possible that parallel tests now underway on the transversely framed *Ocean Vulcan* and *Clan Alpine* will show a difference.

Another hypothesis suggests that portions of the structure incurring high locked-in stresses during fabrication adjust themselves because of slip in nearby riveted seams. In this manner stress peaks are reduced with a possible decrease in the incidence of cracking. There are still other plausible proposals, some of which might yield valuable findings if they were studied.

The direct data on the Bethlehem Fairfield ships might be validated by a careful survey of steel distribution and quality. It would be necessary to establish that the quality of this steel was no different from that of the general supply, or that the steel in critical locations came from other mills than Bethlehem-Sparrows Point rolling mill. If it should turn out that better steel was used in the critical locations, the riveted seams could not be given any credit for reducing the susceptibility of the hull to cracking. It is suspected that even after completion of a laborious steel survey,

the findings would be statistically weak. There is little hope of validating the other direct evidence.

Tests on the transversely framed vessels *Ocean Vulcan* (welded) and *Clan Alpine* (riveted) will double or triple our present knowledge of the influence of riveting on the stress distribution. There is a need to know more about the relative constraint in riveted and welded joints. Tests of typical riveted joints at low temperatures would be good for comparison with welded design detail tests now under way.

SUMMARY

A formidable array of objections has been assembled in dispute of each part of the evidence. Summarizing the discussion we find that practically all evidence must be discarded for one reason or another, only a few shreds remain valid. The findings are summarized below with suitable qualifications.

A. Facts regarding the relation between the method of fabrication and the incidence of cracking.
   1. Both types of structures crack.
   2. The characteristics of the fractures in the two types of structure are similar.

B. Facts regarding the relation between the method of fabrication and physical parameters which are known to influence the incidence of cracking.
   1. Stresses locked in the welded decks of ships are not appreciably affected by the presence of riveted seams in either the deck or side shell.
   2. Riveted joints may slip in service at moderate loading, (above 6000 psi. shear stress on the rivets).
   3. The shear deflection in a riveted seam is usually less than $^1/_{32}$ in. when it slips in service.
   4. Extensive rivet slip might occur without appreciably increasing the deflection of the hull (see Fig. 2, Hypothesis 2).
   5. Rivet slip under service loads may be accompanied by an increase of stress at critical locations in the structure.

CONCLUSIONS

In considering the following conclusions it should be recalled that the study herein relates to the influence of the fabrication method on the incidence of cracking, and it should be re-emphasized that buckling and resistance to the propagation of cracks are not subjects of discussion.

1. From the evidence examined, it cannot be determined whether a welded or a riveted structure is more susceptible to the inception of cracks.
2. Rivet slip may occur at loads within the normal operating range.
3. Rivet slip could result in an increase of stress in critical portions of the structure.

ACKNOWLEDGMENTS

Most of the thoughts expressed in this paper stem from discussions which the author has had with other interested engineers and scientists. These benefactors are too numerous to mention individually. The author wishes to thank Paul Ffield who revealed many new facts used in this paper and G. M. Boyd who assisted by supplying data on the British tests. Gratitude is also expressed to Dr. W. R. Osgood, E. E. Johnson and Miss M. C. Crook, all of the David Taylor Model Basin, for their patience in reviewing and editing the paper. Finally, the cooperation of the following organizations is appreciated for permitting the release of hitherto unpublished facts on the subject: The Bethlehem Steel Co., Shipbuilding Div.; the U. S. Coast Guard and the Ship Structure Committee.

BIBLIOGRAPHY

1. "The Design and Methods of Construction of Welded Steel Merchant Vessels," July 15, 1946. Report of a Board of Investigation Convened by Order of the Secretary of the Navy, Government Printing Office. Reprinted in THE WELDING JOURNAL, **26** (7), 569–619 (1947); **25** (1), 5–18 (1946); **23** (9), 789–807 (1944).
2. "Technical Progress Report," Ship Structure Committee, THE WELDING JOURNAL, **27** (7), Research Suppl., 377-s to 384-s (1948).
3. "Structural Failure of a Riveted Ship," MacCutcheon, E. M., Proceedings of the Merchant Marine Council, U. S. Coast Guard. Reprinted in THE WELDING JOURNAL, **27** (1), 52–54 (1948).
4. "Investigations of the Structural Characteristics of Destroyers *Preston* and *Bruce*," Kell, C. O., Part I, *Trans. Soc. Naval Architects Marine Engrs.* (1931); Part II, *Ibid.* (1940).
5. "Structural Investigations in Still Water on the Welded Tanker *Neverita*," Part I, Bull, F. B., *"Developments in Instruments for Measurement of Strains and Deflections in Ship Structures,"* Part II, Shepheard, R. B., and Turnbull, James *"The Tests and Their Results,"* Inst. Naval Arch. (1946). Reprinted in THE WELDING JOURNAL, **25** (12), Research Suppl., 821-s to 843-s (1946).
6. "Hogging and Sagging Tests, M. V. *Neverita*," Admiralty Ship Welding Committee, His Majesty's Stationery Office (1946).
7. "Structural Investigations in Still Water on the Tanker *Newcombia*," Shepheard, R. B., and Bull, F. B., North East Coast Institution of Engineers and Shipbuilders (1947).
8. "Hogging and Sagging Tests, M. V. *Newcombia*," Admiralty Ship Welding Committee, His Majesty's Stationery Office (1948).

Riveted Vs. Welded Structure with Regard to the Incidence of Cracks in Ships

Discussion by D. P. Brown

In the following comments on this very interesting paper I wish to explain that wherever reference is made to a Liberty ship as being "all-welded" it is intended that reference is made to that type of ship in which the shell, decks and other longitudinal material are completely welded, irrespective of whether the side frames are welded or riveted, as I do not believe that the method of attaching the side frames has any material effect on the problem under discussion. I do not believe that there can be any quarrel with Mr. MacCutcheon's statement that there has been ample experience to demonstrate that the riveted structure has certain advantages in respect to the ability to prevent buckling and the ability to resist the propagation of cracks. I must admit that when it was first decided to introduce some riveted longitudinal joints in the all-welded Liberty ship hulls I was hopeful that the introduction of such joints would not only provide barriers against the propagation of cracks but that these joints would also reduce the incidence of cracking.

In the early stages of the operation of the Liberty ships the incidence of cracks attained a very alarming rate and one which, in my opinion, was considerably beyond that which would normally be expected based upon experience with riveted structures. I gather that Mr. MacCutcheon may not agree with me entirely in this matter. It is true that cracks were not completely unknown in riveted ships but in most cases these occurred in ships of comparatively old age where deterioration had already become evident or in ships of inadequate scantlings based upon present day standards. Neither of these conditions was present in the Liberty ships and investigation of the cracking appeared to indicate that in the all-welded ships, or in large all-welded areas of otherwise riveted ships, certain details were far more critical than in the completely riveted ship and there appeared to be considerably greater susceptibility to minor defects in workmanship. As a result of these investigations changes were made in the original details such as the introduction of radiused hatch corners, the fitting of detached bulwarks, the serrating of bilge keels and the rounding of scupper and accommodation ladder cuts. Concurrently with these changes a great publicity campaign was instituted emphasizing the necessity for careful workmanship and proper controls of erection and welding procedure.

These measures soon had a very noticeable effect in reducing the incidence of fractures but before a great deal of experience had been gained with the improved structure it was also decided to add the riveted crack arrestors so that the effect, if any, of fitting the riveted joints could not immediately be separated from the effect of the changes in details and improvement in workmanship.

Mr. MacCutcheon has cited some figures for a selected group of 667 vessels operating in the winter of 1944–45 and which indicate that the incidence of fracture in the ships with crack arrestors was more than three times that in the all-welded ships. It is presumed that he has included in the vessels having crack arrestors, those with riveted shell seams and those having only one or two riveted joints in the deck or at the gunwale on each side and that in the fractures counted he has included only those which occurred in the effective strength decks, shell or appendages thereto, within the midship portion of the vessels, excluding the various miscellaneous fractures which may occur in bulkheads and other internal structure or at the extreme ends and which are of the type as could not reasonably be expected to be affected by the riveting of the shell seams or the introduction of a few riveted crack arrestors.

In the American Bureau of Shipping we have been keeping continuous records of all reported failures on those vessels under our surveillance, from the time the first vessel was placed in operation, in an effort to determine the effect of the various modifications, and our records indicate results which are quite at variance with those cited by Mr. MacCutcheon. In our records we have considered the Liberty ships as being of five separate types and for these five types the records of ship-months of operation up to July 1, 1948 and of fractures occurring in the decks, shell or appendages thereto, within the main portion of the hull structure are as follows:

Type	Ship-months of service up to 7/1/48	Number of fractures	Fractures per 1000 ship-months
All-welded with original details	25,200	408	16.2
All-welded with improved details	17,300	52	3.0
All-welded with improved details and crack arrestors	41,200	134	3.3
Riveted seams with original details	4,000	14	3.5
Riveted seams with improved details	13,800	35	2.5

These figures can lead to many interesting speculations but since the point under discussion at the present time has to deal only with the effect of riveting on the incidence of fracture, I will confine my comments to this particular matter. It would appear that the incidence of 3.3 fractures per 1000 ship-months of service for the all-welded vessel with improved details and with crack arrestors as against the incidence of 3.0 fractures for the corresponding vessel without crack arrestors would indicate an adverse effect due to the fitting of crack arres-

D. P. Brown is Chief Surveyor of the American Bureau of Shipping, New York, N. Y.

The paper by E. M. MacCutcheon is published in this issue page 111.

tors but this is by no means anywhere near as great as the more than 3 to 1 ratio indicated by Mr. MacCutcheon's figures. Mr. MacCutcheon has quite properly pointed out that his figures are undoubtedly influenced to a great degree by the policy of selecting those ships with riveted crack arrestors for the more arduous services which were in force during the period covered by his records. This effect of selection will always be present, but to a lesser and lesser degree as the records increase and it is quite possible that this may still account for the apparent unfavorable effect of the riveted crack arrestors even in our over-all figures.

Another interesting fact to be obtained from these records is in respect to the benefits of the improved details. It should be noted that for the all-welded ship with the original details the incidence of fractures is 16.2 per 1000 ship-months and that this figure was reduced to only 3.0 in the corresponding ship with improved details. For the ships with riveted seams the incidence is 3.5 per 1000 ship-months with the original details and it is reduced to 2.5 with the improved details.

As I stated before, there was, concurrently with the program of changing details, an intensive campaign to improve the quality of the workmanship and to establish more rigid controls on shipyard practices and procedures, and to just what extent this campaign contributed to the improvement in the fracture records can never be definitely established. It is not reasonable to believe, however, that the yard building the ships with the riveted seams did not have some room for improvement as the construction program progressed and that it did not also obtain a part of the improvement in the fracture records as a result of this campaign.

Mr. MacCutcheon has suggested that there is a possibility that the steel used in the ships with the riveted seams might have been of better than average quality. We cannot disregard this possibility entirely, but such investigations as have been made have failed to show any differences of such magnitude as might be expected to account for the wide difference in fracture records.

If we eliminate the effects of the material and accept the premise that construction practices were more or less uniform and subject to a corresponding degree of improvement as time went on, we can only account for the wide difference in the records of the two types of ships with the original details and the considerably greater effect of the changes in details and improved practices in the case of the all-welded ships, by accepting the premise that the ships with riveted seams were far less susceptible to minor defects resulting from workmanship or construction practices and to square hatch corners, square cuts in sheerstrakes, continuously welded bilge keels, etc.

The foregoing discussion relates only to the comparative records for the all-welded vessels as against those for the ships with all of the shell seams riveted and it must be admitted that the records for these ships which had only one riveted joint at the gunwales or at the most only one at the gunwales and one in the upper deck on each side are nowhere near so conclusive. However, if there is any effect on performance of the introduction of a large number of riveted joints, then it is only reasonable to expect that there should be some effect due to only one or two such joints even if only to a considerably lesser degree. It is quite easy to establish just what is an all-riveted or an all-welded structure but it is impossible to define the different stages between these extremes as to when a structure might be said to progress from a riveted structure with some welding to a welded structure with some riveting. It is hard for me to believe that there is any magic point in this progression at which there is a complete flop-over from one set of conditions to the other. I believe that if we accept that the superiority of the fracture records of the ships with riveted shell seams is, to any degree, due to the riveted seams, then it is impossible to believe that the introduction of only one or two such joints can have anything but a beneficial effect, even if only to an insignificant degree.

I believe that Mr. MacCutcheon has done a very splendid job in his attempts to set forth all of the evidence pro and con on this very important subject and that even though his investigations have not produced any positive results, nevertheless they have given us all considerable food for thought. It is to be hoped, that as the many investigations progress and the service records accumulate, we will obtain a much clearer insight into this problem.

Discussion by Wendell P. Roop

The subject of this paper is more restricted than appears at first sight. Perhaps it can be paraphrased so: Does welding favor brittleness? The author concludes that we have no answer. My comment is in the vein: "If so, why?"

The inception of a progressing crack is a more elaborate process than was once thought. In laboratory specimens it is visibly apparent that a crack is present in a notched specimen soon after passing the nominal elastic limit; and does not the author have a standing offer to find cracks on any ship in service? It is an inadequate view of the matter to suppose simply that stress concentration causes cracks and that, once formed, they intensify the concentration and so lead to rupture. The choice does not lie between structures with cracks and those with none, but between brittle cracks and ductile cracks.

The question thus becomes this: Are the cracks in a riveted structure more likely to be ductile than in a welded structure? Since facts on this point are inconclusive, we must still depend on inference.

The usual thought has been that slip in riveted joints adds to the power of a structure to wash out localized effects, whereas in welded joints this power is wholly dependent on ductile flow in the metal. One might suppose that in the *Alexander* the riveted joints had suffered ankylosis, a common effect of old age.

Wendell P. Roop is connected with Swarthmore College, Swarthmore, Pa.

The inclusion of Item 5 among the indisputable facts seems a trifle hasty. Will not slip generally occur first at those points where stress exceeds the capacity of the joint to resist it, and so shift the burden toward other points better fortified or previously less highly stressed?

The absence of laps or straps in flush seams of the sort usual in welding hinders contraction in width, but so long as the plate is free to contract in thickness, triaxiality remains small.

There remains the possibility of a metallurgical effect on the brittle transition temperature. Grossman and MacGregor, last May, reported data to show that the metal in the welds is always more ductile than in the base plate. A small contrary effect was found at 1 in. from the center-line of the weld, the transition temperature being raised 5 to 20°. This seems a small price to pay for the benefits of welding, but its existence should not be ignored.

Discussion by David Arnott

The author makes a distinction between the inception of a crack and its propagation. It is axiomatic that every crack must have a beginning but a crack which merely starts but does not propagate is of no practical concern. There is no question in my mind but that welded ships are more susceptible to the inception of plate cracks than riveted ships at least during course of construction. When a plate cracked in the Yard in a riveted ship it was usually because of cold flanging, repeated furnacing during the fitting of shaped plates, abnormally high carbon, sulphur or phosphorous content or for some other satisfying reason. When we came to build welded ships, plate fractures kept occurring in the shipyards for reasons which were not so obvious. In the absence of any external loading the fractures could only be properly attributed to internal stresses incidental to the process of welding whether one prefers to call them shrinkage, thermal, residual or just plain locked-up stresses. Such failures were gradually reduced in numbers as the importance of adhering to proper welding sequences and technique became more fully recognized but that they could happen during course of construction was not a very good augury for the satisfactory behavior of the structure under service conditions. I have always felt that despite the apparent results of some of our welding research we were somewhat premature in discounting the importance of residual stress as a major contributing factor in our welded ship failures.

The structural failures of the riveted ships cited in the paper are not quite analogous to our welded ship failures. The *Oakey L. Alexander* managed to live up to her christian name for 31 years before breaking in two. I have not had an opportunity of examining her scantling plans but I would be very much surprised if the effective area of her strength deck would compare at all favorably with our modern standards for longitudinal strength. The *Leviathan* and *Majestic* were practically sister ships both of which experienced a partial failure of the upper structure after some years of transatlantic service primarily because of inadequate compensation in way of elevator and other openings in the strength deck in the vicinity of an abrupt discontinuity in the structure resulting from a line of expansion joints in the houses directly above. In short, one could point a finger at the reasons for the structural failures which have occurred on riveted ships. The failures on our completely welded ships, practically all new vessels, were much more mysterious. Experience has shown that once a crack started it was liable to spread with lightning rapidity across the deck and down the sides or across the bottom and up the sides until the structure had failed completely. Even where the crack originated in a member which was structurally unimportant such as thin plating between hatches or a bulwark rail and which, although not included in the longitudinal strength calculation are subject to stress, the crack was liable to spread into the main hull structure if the light plating was welded thereto.

The comparative immunity of the Bethlehem-Fairfield ships with riveted shell seams has not been satisfactorily explained by any of the research projects which have so far been carried out. It is hoped that when the British experiments on actual ships, both welded and riveted, to which the author refers in his paper are finally completed additional light will be thrown on this important problem. The author seems to incline to the opinion that the only value of the longitudinal riveted straps or gunwale connections is to limit the propagation of cracks but I am not so sure that such is the case. Until such times as we have more information on the subject ordinary prudence will dictate the policy of installing crack arrestors in our new welded ships of the larger sizes as a precaution against complete failure. The *Oakey L. Alexander* and other riveted ships which broke in two were full of crack arrestors which obviously failed to function as such. The installation of these riveted crack stoppers in welded ships should be looked upon as a temporary expedient as it is no answer to the problem of how to build large *all-welded* structures which can be relied upon to be entirely satisfactory in service. Meantime, we are gaining more and more experience on welded ships in service and the policy of analyzing each and every structural failure hand in hand with a suitable program of fundamental research will undoubtedly go far toward providing a complete solution to our problems.

Mr. MacCutcheon has been unusually modest in submitting his conclusions. I agree with No. 2. So far as No. 1 is concerned I feel, for reasons already stated, that a welded ship is more susceptible to the inception of cracks than a riveted ship. With regard to conclusion No. 3, while I am prepared to admit that rivet slip could result in an increase of stress in critical portions of the structure it could just as easily result in stress reduction.

David Arnott is a retired Vice-President and chief Surveyor of the American Bureau of Shipping, now retained as a consultant. He is a Past-President of the American Welding Society.

The author has been very fair in his handling of the extremely difficult subject of the relative incidence of cracking in ships' structures fabricated by riveting and welding, respectively. His lack of bias and the manner in which he has presented and discussed the various arguments pro and con are worthy of emulation by other writers of technical papers.

Discussion by John Vasta

This paper has attempted to elucidate a very confusing subject. It appears however, that in going through the tortuous paths of direct and indirect evidences, hypothesis and postulates the author has not succeeded in adding the clarity desired. In fairness however, it should be noted that the pitfalls are many as the subject requires quantitative evaluation of too many elusive and somewhat obscure variables. This discussor finds it difficult to accept Conclusion 1 of the paper, and wishes to discuss two elements which have a bearing on the question of susceptibility to incipient cracking, namely, the matter of stress concentration, and the effect of the residual stresses.

A welded structure, in my opinion, is more susceptible to incipient cracking than a riveted similar structure for the following two reasons:

(1) The process of welding *per se* delineates clearly the boundaries of a geometrical discontinuity and is generally responsible for the formation of sharp notches. To illustrate, by welding all the component elements of a square hatch corner, for example, the acuity of this geometrical notch becomes well defined and established. This is not the case for a hatch corner structure assembled by riveting. It is apparent, therefore, that the acuity of a notch is more pronounced in a welded structure than in a similar riveted one. Since the magnitude of the stress concentration is a function of the acuity of the notch, the stress level at the base of such a notch should be higher in a weldment than in a comparable riveted assembly. We know that the inception of a crack depends largely on the stress level existing at the immediate region where the crack initiates. This means that the fracture stress is likely to be reached sooner in a welded structure than in a riveted structure of the same geometrical configuration.

(2) In addition to the severity of the stress concentrations existing at the base of a notch, the process of welding introduces a system of residual internal stress of high magnitude at the base of such notches. It is readily accepted that these residual stresses are nonexistent in a riveted structure. However, we cannot admit as yet that the presence of residual stresses at the base of a geometrical discontinuity has no significant effect on the strength behavior of a welded structure. Recent published work* indicates that a tensile residual stress existing at the base of a notch has a significant effect on the fatigue strength of steel, whereas the same tensile residual stress present in unnotched plates plays no significant part. This is the first time that experiments point a guilty finger to the tensile residual stress as being important under certain conditions, fatigue and presence of notches. A weldment containing a geometrical discontinuity conceivably may have present tensile residual stresses of high magnitude in the three mutually perpendicular planes. This we know results in a triaxial stress system, a condition that, admittedly, theory tells us, should be avoided. The question to be asked here is whether or not a triaxial stress system could exist at a base of a geometrical discontinuity of a riveted structure. Obviously, the answer to this is in the negative. Hence, we should expect the welded structure to offer a higher probability to incipient cracking than a riveted assembly of similar details.

John Vasta, Naval Architect, Navy Department, Bureau of Ships.

* The Welding Journal, **27** (8), Research Suppl., 421-s to 425-s (1948)

Author's Closure

The author of this paper is honored to receive discussions from those members of the shipbuilding profession who have contributed their comments. As stated in the paper, this study yielded very little in the form of positive findings. Some important factors are brought out in the discussions which add to the available information on the susceptibility to fracture of riveted and welded hull structures.

Captain Roop has presented several of his customary thought twisters based on the subject of the paper. He makes a very interesting statement which bears repeating: "the choice does not lie between structures with cracks and those with none, but between brittle cracks and ductile cracks." Mr. Arnott also supports this point with his comment that nonpropagating cracks are not important. Captain Roop has alluded to the author's statement that practically every welded ship contains numerous small cracks. Most surveyors of ship hull structure will support this observation; a fact which emphasizes the importance of nonpropagating cracks.

Captain Roop has questioned the inclusion of Item 5 among the indisputable facts. Perhaps the paper should have distinguished more clearly between the local and over-all effects of rivet slip. In Item 5 it is stated that "rivet slip under service loads may be accompanied by an increase of stress at critical locations in the structure." This statement referred to the calculations described in the paper and the calculations applied to over-all adjustments in the hull and not to local effects. It is mentioned elsewhere in the paper that local slippages may, and probably do, occur with corresponding readjustment of stress distribution. Detection of such redistribution in actual structures would yield important findings, but the selection of locations for study is attended by apparently insurmountable practical difficulties.

Mr. Brown has raised two questions with regard to the statistics in the paper which relate the presence of riveted crack arrestors to the incidence of cracks. The statistics include only Class 1 and 2 fractures and therefore correspond to Mr. Brown's data in this respect. The Bethlehem-Fairfield ships were included, however,

and make up about 1/8 of the group without crack arrestors and a somewhat smaller proportion of those with arrestors. Mr. Brown kept the Bethlehem-Fairfield ships separate. To assist in rationalizing the differences Mr. Brown has graciously forwarded to the author a breakdown of the structural failure data included in his comment. On examining this breakdown one other difference was noted; Mr. Brown's tabulation lists casualties, whereas the paper under discussion lists fractures. Most casualties involved more than one fracture, the average being about three fractures per casualty.

The casualty data for the winter of 1944–45 were excerpted from Mr. Brown's tabulation. The incidence of casualties was found to be 70% higher for the ships with crack arrestors than for those without. This is good agreement with the data presented in the paper when it is realized that a wide dispersion is characteristic of statistics based upon such small samples and that the figures being compared are not coterminal.

It was reassuring to find that some additional pieces of evidence bearing on the subject of the paper had been included in the comments. Mr. Brown shows by his tabulation that improving the structural details on the all-welded ships resulted in a far greater improvement in structural performance than was brought about by a corresponding improvement in structural details for those ships which had riveted seams. (The items on Mr. Brown's tabulation have been numbered 1 to 5 for the purposes of this reply. Compare Group 2 with Group 1 and Group 5 with Group 4.) This type of comparison eliminates some of the variables which upset a direct comparison of Bethlehem-Fairfield's ships with all other Liberty ships. Questions of workmanship and steel quality are no longer important because the comparison is between the same ships with and without modification. There is, however, one wild variable in this comparison, namely: the equality of operating conditions. During the winters of 1942–43 and 1943–44, the operating conditions for the Liberty ships were considerably more severe than during later winters. This was partly due to inclement weather conditions and partly due to the fact that many of the ships were operating to Murmansk, and in the North Pacific. The data were tested to see if all groups were equally affected by the severe weather. The following tabulation resulted.

Group	Type	Casualties per 1000 ship-months of service: All service up to July 1, 1948	Casualties per 1000 ship-months of service: Service from May 1, 1944, to July 1, 1948
1	All-welded with original details	16.2	3.7
2	All-welded with improved details	3.0	2.2
3	All-welded with improved details and crack arrestors	3.3	3.3
4	Riveted seams with original details	4.5	2.9
5	Riveted seams with improved details	2.3	2.0

It will be noted that the tabular values, for operation up to July 1, 1948, do not agree exactly with those included in the comment. Mr. Brown has indicated corrections which have been applied to the revised figures above. It is clear that the service during the winters of 1942–43 and 1943–44 resulted in a much higher fracture incidence in some groups of Liberty ships. Since the number of various groups of vessels in operation was not constant throughout, this severe condition affected some groups more than others. Consider the last column for casualties from May 1, 1944, to July 1, 1948. Comparing the casualties per one thousand ship months of operation for Group 1 with Group 2, it can be seen that the fracture incidence was reduced to 60% by improving design details. Comparing Group 4 with Group 5, we find that the fracture incidence is reduced to 69%. The difference between 60 and 69% is no longer significant in light of the fact that one of the figures involved is based upon only four casualties. Here, again, we are confronted with the disappointing necessity of concluding that the evidence shows nothing significant regarding the relative incidence of cracking in welded and riveted ships.

Mr. Arnott has presented an important piece of evidence in pointing out that cracking during construction was much more widespread for the welded hulls than it had been for riveted hulls. This is a piece of direct evidence which was overlooked in preparing the paper. Mr. Arnott rightfully warns against predicting the incidence of failure of ships in service by making use of data from ships under construction. Everyone will agree, however, that the failure incidence during construction is a rough indicator of the direction of a trend and that a higher incidence of fracture in completely welded structures could be expected.

Mr. Vasta has included some very convincing explanations of why the welded structure should be more susceptible to cracking than the riveted structure. He has pointed out that welding creates worse notches and higher locked-in stresses. We are all attracted by the logic of such statements but similarly convincing arguments can be presented to support the opposing viewpoint. Although the logic is appealing we should be cautious in accepting these speculations even though equal consideration is given to the opinions supporting opposing views.

Considering the controversial nature of the subject, the discussors have taken an extremely objective viewpoint. This sort of healthy situation is bound to accelerate our understanding of the problem. The data presented in the paper reinforced by the data and reasoning included in the comments do not warrant a positive conclusion but provide an adequate basis for an opinion. The author holds the opinion that the incidence of cracking is higher in welded than in riveted structure. Even to this, a caution must be added: the opinion is based on existing structures; improvements in steel, in design, in workmanship or in weldability controls could bring the quality of welded structure up to or above that of the riveted structure.

Fabrication of Structural Steel Sections

Large and unusual structural sections may be fabricated by submerged melt welding

by J. M. Tippett

THE designer as well as the fabricator for some years has resorted to fabrication by welding when confronted with a problem of using or supplying large structural sections or sections not ordinarily carried in stock. Some recent designs, particularly in the field of heavy earth-moving equipment, have called for stiffening members of nonuniform cross section or members of a size or type not usually rolled. Here, too, fabrication by welding is the answer to the problem of supplying parts that are not readily available.

A considerable increase in the fabrication of structural sections has resulted mainly from the current shortage of steel. Also responsible is the available production capacity of welding machines and forming equipment that were acquired by many fabricators during the war. Heavy presses and brakes make it possible to form deep channels and angles, which are welded together to form the widely used box section beam. Where formerly heavy I- and H-beams were cut out to form nonuniform sections in engine bases or parts of beams and dipper sticks, the entire member is now generally fabricated from flat plate. When the required member is so large as to be beyond rolling capacities, or heavy enough to be considered a special, in these days of steel scarcities, it is only logical that it be fabricated by welding. Some users and suppliers of structural shapes, handicapped by their geographical location, have found it economical to fabricate even normal sizes of beams as needed rather than carry large stocks of all the necessary sizes.

Automatic welding is suited to this type of fabrication by the nature of the welds employed, which are usually long fillets, butts or laps. Unionmelt welding is especially suited to this type of work. Submerged melt welding though usually applied automatically differs from most automatic welding. Other methods of arc welding, either hand or automatic, use a coated electrode which produces a gaseous shield to protect electrode and weld puddle. The submerged melt welding process uses a bare rod and a separetely applied granular material which covers the end of the welding rod and the molten puddle. Part of this composition melts in the welding heat and submerges the end of the rod and the fluid weld metal. This makes possible the use of high-current densities, and provides a complete liquid shield beneath the granular material. No arc and usually no flash is visible. Whereas shielded arc welding makes use of current densities from 3000 to 10,000 amp. per square inch of steel electrode cross section, in submerged melt welding current densities up to 40,000 amp. and more per square inch are normally used. The high current densities make possible the deep penetration, high welding speeds and high quality of these welds.

The jigs and fixtures required for fabricating steel sections can be quite simple, and are relatively inexpensive even when motorized so that the weldment can be positioned between welds without removing it from the jig. Motorized equipment for this work has often been made by using a standard welding positioner at one end and a trunnion mounted on an A-frame on the other. The major requirement of the jig when fabricating such sections as I- and H-beams from plate by fillet welding, is to position the weld for downhand work. Usually the beam which has been assembled and tacked together is

Fig. 1 The parts of the beam are held in position while tacked together by metal arc

J. M. Tippett is Manager, Unionmelt Service, Eastern Division, The Linde Air Products Co., New York, N. Y.

This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

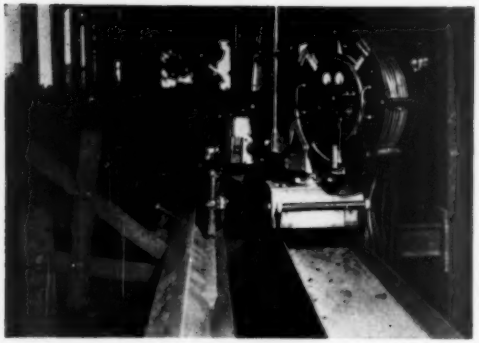


Fig. 2 Typical installation with welding carriage supported on track above the work

rotated so that the flange being welded is 30° from the horizontal. The two welds forming the "T" are then adequately backed up by the flange itself. If the beam is positioned so that the welding rod is pointed directly at the seam, there is danger of weld run-out unless fit-up is perfect and the pieces are held tightly together during welding.

It is seldom practical to use the welding jig for assembling and fitting the section. The jigs for fitting are similar to those for welding except that they are usually heavier. The members of the beam are held in close contact by heavy stiff backs with wedges driven under them until they have been tacked. Figure 1 shows a stiff back and wedge holding one end of a medium sized H-beam while it is tacked together by manual metal arc welding. Because the two welds in the center of the flange tend to warp the plate and pull the edges of the flange toward the web, the plate forming the flange is sometimes prebent in the opposite direction approximately $^1/_8$ in. per foot of flange widths so that the finished flange will be flat. Flange distortion, if objectionable, can also be taken out in a press after welding.

After the beam is fitted up, it is taken to the welding position. In its simplest form this consists of two major parts; the welding machine track and its supports, and the frame to support the member to be welded. Figure 2 illustrates the basic setup of this type. The base is

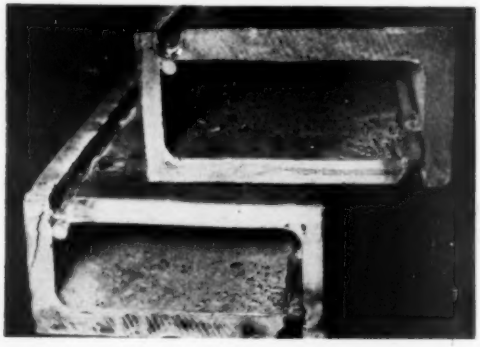


Fig. 3 Box beams ready for submerged melt welding

Fig. 4 Box beams produced by welding two facing "U" sections

made of heavy beams. Vertical members welded to this carry the cantilever arms on which the track is mounted. In front of this structure and below it, the frames are erected which hold the weldment. In this case, they are made up of flat stock bolted together, so as to accommodate various sizes of beams and allow for changing the angle between welds when working on beams whose flanges are not the same in width. Beams of the size shown will normally have a $^3/_8$-in. thick web and $^1/_2$-in. thick flange. They are Unionmelt welded at speeds from 12 to 20 in. per minute or faster, using approximately 600 amp. and 30 v. The variations of these basic requirements for fixtures and procedures may be as numerous as beam sizes and designs.

Rolled angles 12 x 6 x $^5/_8$ are easily fabricated into box sections, by fitting them as shown in Fig. 3. A corner butt weld is used, backed with a $^1/_2$-in. diameter rod. A 30° bevel on the longer leg of the angle forms a vee-groove. One hand pass and three machine passes at 12 in. per minute complete the weld.

In this same shop a square box section is also fabri-

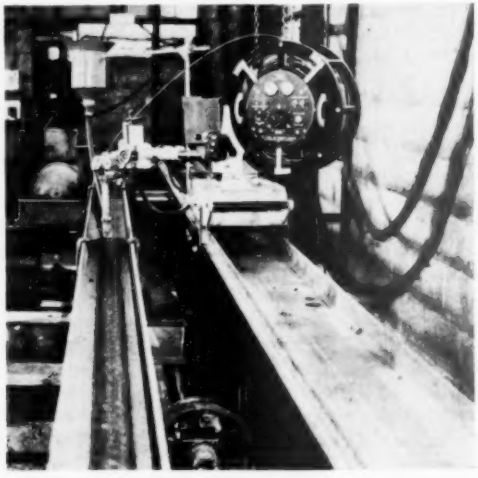


Fig. 5 Fabrication of deep ship channel from two 4-in. angles

cated from flat plate formed into U sections and butt welded as shown in Fig. 4. The plate is 1 in. thick with a 22° included bevel in the joints. A $^3/_8$-in. backing bar is used under the weld and five machine passes are made at speeds from 13 to 9 in. per minute. Welding current is from 900 to 1000 amp. The use of rolled shapes in combinations to form deep channels or other heavy sections, and the addition of flat plate to increase web depth or flange width, is standard practice.

Figure 5 shows two heavy 4 x 4 in. angles being

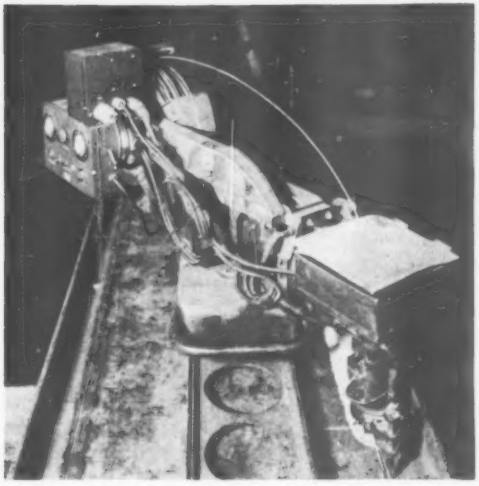


Fig. 6 Large channel fabricated by welding angles to web plate

Fig. 8 The portable welding machine is guided by the curved flange of this large circular girder

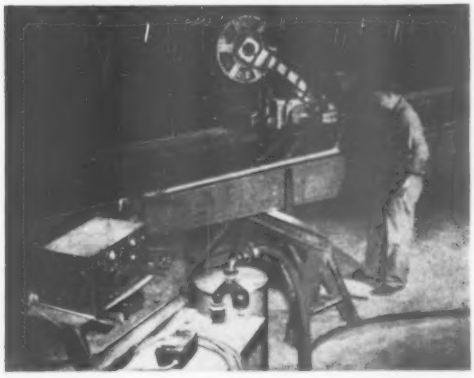


Fig. 7 Tapered box-section stress member fabricated for earth moving equipment

Fig. 9 A templet guides the welding head to produce this irregular-shaped section

Fig. 10 Welding head mounted on cantilever beam welding both inside and outside seams of tubular sections

Fig. 11 A low gantry supports the welding head for making longitudinal and girth welds in the production of piling

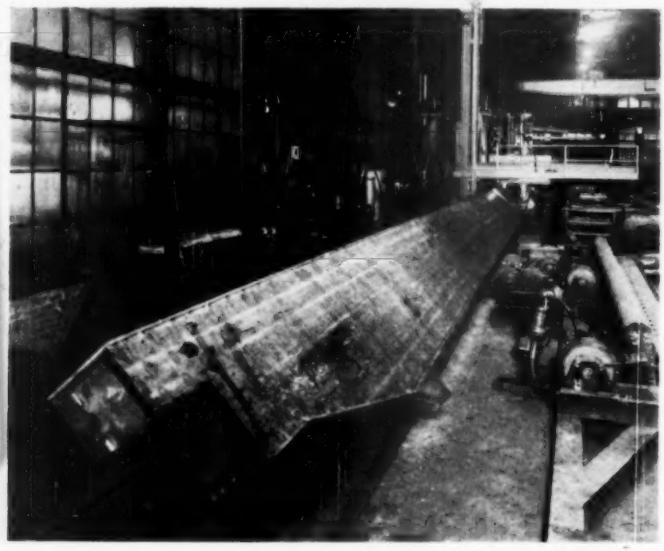


Fig. 12 A wall-type crane carries the welding head for fillet welding a large girder

joined to form a deep ship channel 20 ft. long. Welding is done entirely from one side and refractory composition is used to back the weld. The use of two angles and a 25-in. wide, flame-cut plate to fabricate a 33-in. wide channel is shown in Fig. 6. These butt welds are made in two passes, one from each side at 18 in. per minute using 700 amp. on the first side and 900 on the other. This gives a fully penetrated weld of considerably greater strength than the parent metal. The track and welding machine can be placed directly on the workpiece when welding sections of such large size.

The fabrication of members of nonuniform cross section is shown in Fig. 7. Corner-butt welds are used to join the four pieces of flat plate that make up this simple straight-taper box section. Fabrication is readily accomplished by mounting the beam so that the weld being made is level and in the downhand position.

Large arches and members having curved sections may require more complex jigs, though in many cases a portable machine can be placed directly on the piece being welded. By employing guiding devices, the machine will accurately follow long curves and sweeps. Figure 8 shows a machine with such a guiding device depositing a fillet on a 42-ft. diameter girder. Sections having reverse curves or curves of varying radii can be welded by mounting the welding machine on a device which will follow a template. Fig. 9 shows a welding head mounted on a traveling pantograph arrangement. With this equipment, reverse curves of small diameter can be negotiated and contour welding of most any type can be accomplished.

Fabrication of large tapered tube sections is easily done by any shop which ordinarily uses the process for pressure vessel work. The sections of tube are first rolled into their designed diameters and the straight seam welded inside and out. Sections are then fitted together and tacked. The entire beam is placed on a set of heavy rolls and rotated while the round-about fillets are made. Figure 10 shows this work being done with a highly flexible method of mounting the welding equipment over motorized traveling and turning rolls. The welding head is mounted on the end of a cantilever beam which moves vertically only. The rod reel is mounted at the opposite end of the beam so that it does not limit the diameter in which inside welding can be done. The carriage and rolls combination has a single motor and variable speed unit so geared that the drive can be shifted from turning rolls to carriage travel for round-about or long seam welding.

The accompanying photographs illustrate a few of the variations of equipment for mounting and jigging to permit the use of the process on special work. Figure 11 shows the welding head on a low gantry making circumferential welds on a section of piling which combines pipe and I-beams. The specially made carriage straddles the work and is positioned by hand for each weld. The pipe rests on turning rolls that are driven by

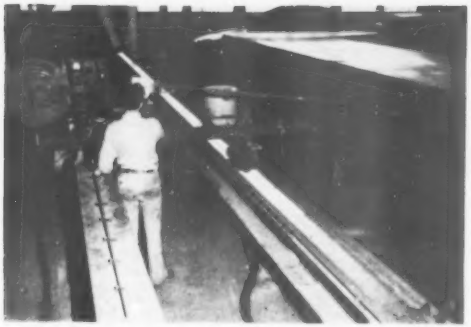


Fig. 13 Welding of diaphragm plates to side sheets in the fabrication of a large girder for a gantry crane

Fig. 14 An extended nozzle welds a 6-ft. seam through an opening 1 ft. square

an electric motor operating through a reduction unit made of spare parts. Figure 12 shows the equipment mounted on a wall type crane fillet welding a large girder. This type of installation is extremely flexible. Beside controlled movement of the crane along its ways, the platform on which the welding equipment is mounted can be raised or lowered and the welding head can be moved along the platform at right angles to the direction of crane travel. Figure 13 shows an interesting adaptation of equipment to allow welds to be made through a 1 ft. square opening 6 ft. deep. In this installation the carriage travels on a beam which is mounted on wheels for manual positioning between welds. Some 13,000 ft. of fillets were made with this unit in fabricating two of the large girders shown. A small funnel for distributing the granular welding composition is attached to the extended nozzle as shown in Fig. 14. The funnel is refilled after each weld is made. The sequence of welding requires that the girder be turned twice. In the first position, the welds are made in, let us say, the lower right corner of each opening. The girder is turned over and welds are made in the lower right and then the lower left corners. The girder is turned back

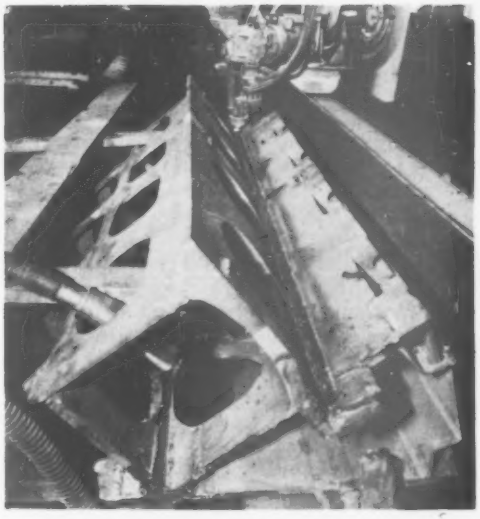


Fig. 15 Heavy plate butt welded to a cast steel stub in fabrication of a Diesel engine frame

to its original position and the finishing welds are made in the lower left corners.

Where extremely heavy sections are being fabricated, fillet welds and double vees can be avoided by using rolled stub sections on cast or prefabricated members and welding on heavy plates using a butt weld. Figure 15 shows how this was done in the fabrication of a rather complex frame for a Diesel engine. Arrows indicate the welds joining the heavy plates to the cast stub section.

The speed, uniformity and deep penetration of submerged melt welding make it particularly suited to the fabrication of structural sections. Of course, welded fabrication offers no competition where standard rolled sections are available. However, even for standard sizes of H- and I-beams, some fabricators have found it advantageous to keep only the widely used beams in stock and to make up the odd-sized beams to order. Since the cost of fabricating almost any desired section is so low, it is now economically practical for the engineer to specify the type of structure that is actually best suited for the job at hand. For instance, the engineer can specify box or re-entrant sections that could not be produced by rolling. Standard H- and I-beams can be made to the exact size required and even tapered sections, whether of I, H, box or tabular form, can be easily made. In larger structures where numerous stiffeners or diaphragms are used, the process and automatic equipment make it possible to weld through openings and in spaces where an operator could not gain access. The accessory equipment required need not be complex or prohibitively costly. All of these factors have led to a considerable use of the Unionmelt process for making a variety of structural parts. We fully expect that the next few years will see a much wider use of this process and many new applications.

Practical Aspects of Inert-Gas Welding

A comprehensive résumé of inert-gas-shielded arc welding including a description of the process, gases used, electrodes, straight vs. reversed polarity, d.-c. and a.-c. welding equipment, control of gas flow, techniques in welding stainless steel, aluminum, copper, magnesium, steel and other metals

By H. A. Huff, Jr. and A. N. Kugler

INERT-gas-shielded arc welding may be defined as an arc-welding process in which the heat is derived from an arc between a nonconsuming electrode and the work and the arc is shielded by a monatomic, inert gas. The principal differences between this method and the older methods are (1) the electrode does not melt and form part of the weld metal, (2) the inert gas provides the shield for the molten metal and the electrode as well as assisting ionization in the arc. Under this broad definition there are many possible applications some of which are eminently successful, others satisfactory and still others which are, at present, of no practical value.

Either alternating current or direct current (straight or reversed polarity) may be used subject to limitations on certain metals, as discussed later. The electrode may be either tungsten or carbon, with tungsten predominating on most applications. For the inert gas both helium and argon are used and both exhibit certain advantages and disadvantages under given conditions of welding current and base metal.

In studying the fundamental aspects of this process it is desirable to consider first, the inherent properties of the arc under the several possible welding power conditions without the complications of base metals. The d.-c. arc on straight polarity operating in an atmosphere of helium will be found to be the hottest arc condition obtainable with this process. This means that the penetration will be greatest with these conditions and this penetration is largely controllable. This intense heat of the tungsten arc in helium means that with identical current values faster travel speeds are possible with helium than with argon, or at the same travel speed less current is necessary with helium than with argon. The arc voltage with helium is higher than with argon and further the slope of the curve of arc voltage vs. arc length[1, 2] is steeper with helium than with argon. This means that with helium a relatively small variation in arc length will result in a greater variation in arc voltage than is possible with argon. This is of particular importance in automatic welding.

Using argon as the inert gas, under the comparable conditions, i.e., the tungsten arc on d.-c. straight polarity, we find a very satisfactory welding arc. This represents the greatest energy obtainable with tungsten-argon arc. However, if compared with the helium arc the lowered heat of the argon arc will be noticed immediately. This is not necessarily a disadvantage since, under some circumstances, the lesser heat of this arc is desirable. However, in automatic welding it is more difficult to secure voltage control in argon as the arc voltage-arc length relation is not as direct.

Still another possibility exists for using d.-c. straight polarity with either helium or argon and that is the substitution of a carbon for the tungsten electrode. Incidentally, this is the only current condition on which it is possible to use the carbon electrode. One of the principal advantages of the carbon electrode is the ease with which the arc may be started. This is especially necessary with low currents on light work or in instances where it is necessary to employ relatively unskilled operators. The carbon electrodes used for this work are prepared with a long taper, Fig. 1, the diameter at the point being the controlling factor in the current to be used with the electrode. Thus by using a large electrode and grinding to a small point it is possible to use heavier currents which would cause overheating of a smaller electrode. About the only disadvantage of the carbon electrode, aside from the relatively rapid consumption of this electrode, is the possibility of the carbon contaminating the base metal, although this does not appear to be borne out by those who use it. Either shielding gas may be used with this electrode.

The next major change in welding conditions is to employ d.-c. reversed polarity. The field of application for this condition is limited for the reason that the cur-

H. A. Huff, Jr., is a Welding Specialist and **A. N. Kugler** is Mechanical Engineer, Technical Sales Division, Air Reduction Sales Co., New York, N. Y.

This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

Table 1—Current Ranges for Tungsten Sizes*–Various Welding Power Sources–Manual Welding

Tungsten size, in.	Direct current			Alternating current			Gas cap size, in.
	Reversed polarity, helium	Straight polarity, helium	Straight polarity, argon	Standard transformers with high frequency and d.-c. component, argon	Balanced a.-c. transformers, no d.-c. component, helium†	Balanced a.-c. transformers, no d.-c. component, argon‡	
0.040	...	...–50	...–65	...–30	...–40	...–40	3/8
1/16	10–20	50–125	65–150	20–115	20–60	...–85	3/8
3/32	20–35	125–225	140–280	100–185	50–100	75–130	3/8
1/8	25–50	200–300	250–375	150–225	75–175	100–200	1/2
5/16	30–75	250–350	300–475	200–340	150–240	175–300	1/2
1/4	40–125	300–475	375–	300–445	175–375	275–410	1/2

* Carbon electrodes, shaped as indicated in Fig. 1, may be used at approximately the same current values, on d.-c. straight polarity only; for size, use diameter "d" at point.
† Use 150-v. tap.
‡ Use 100-v. tap.

rent-carrying capacity of the tungsten electrode is greatly reduced, see Table 1. This is due to the fact that the tungsten electrode heats up rapidly because of the greater heat liberated at the positive terminal (in reversed polarity the electrode is positive), and tends to cause excessive melting of the tungsten at values far below the maximum usable with other current conditions. It will be noted, however, that starting the arc with reversed polarity is quite easy and a very short arc must be held. There is one further feature with reversed polarity that is important to note, viz., the arc has the ability to break up or disperse the oxide films of such metals as magnesium and aluminum. In fact the welding of magnesium was first accomplished with reversed polarity and helium. Other welding power arrangements have largely superseded this one.

Before closing this phase of the discussion of d.-c. welding it seems appropriate to point out that the only application of superimposed high-frequency circuits in this field is for starting the arc without touching the electrode to the work. The high frequency may be used with either shielding gas and the arc on d.-c. straight polarity. In manual welding it is most helpful where welding must be performed in a tight spot in which it is difficult to strike the arc, or on polished stainless steel surfaces where marring of the polished surface must be avoided. Ordinarily, it is not necessary in manual welding. It also proves helpful in some mechanized and automatic welding operations for starting the arc. The high frequency, however, should be used only for starting in either of these conditions and should not be run continuously as it frequently is in a.-c. welding.

The advantages that accrue from the use of a. c. in metal arc welding prove equally valuable in inert arc welding. Further, the problems which arise from the use of a. c. exist in this case also. Thus, the proverbial hard starting of the a.-c. arc creates a problem in starting the tungsten arc particularly at low current values; in fact the a.-c. tungsten arc virtually cannot be started without assistance from high frequency. In addition, each time the alternating current passes through zero, it tends to extinguish the arc, creating unstable welding conditions. This latter condition of instability can be corrected in either of two ways: one

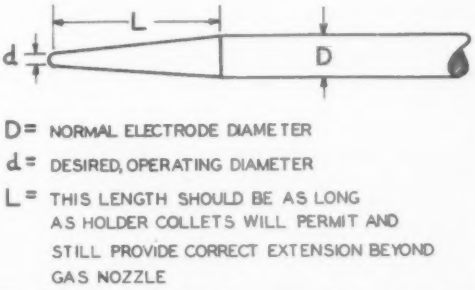

L
d
D
D= NORMAL ELECTRODE DIAMETER
d= DESIRED, OPERATING DIAMETER
L= THIS LENGTH SHOULD BE AS LONG AS HOLDER COLLETS WILL PERMIT AND STILL PROVIDE CORRECT EXTENSION BEYOND GAS NOZZLE

Fig. 1 Preparation of carbon electrodes for inert-gas-shielded arc welding

involves the use of a superimposed high-frequency circuit, the other, the use of specially designed welding transformers which provide balanced a. c. Arc starting may be facilitated by a superimposed high-frequency pilot circuit or the use of a supplementary carbon block on which the arc is first struck and then transferred to the work.

The tungsten arc operating with standard a.-c. transformers, using high frequency, and helium as the shielding gas has little practical value because it is unstable and yields unreliable results. If, however, these same electrical conditions (i.e., normal a.-c. transformers plus superimposed high frequency) are employed with argon as the shielding gas the process is successful. It is particularly useful with those metals that exhibit difficult oxide conditions, normally requiring flux when welded by other methods, e.g., aluminum, magnesium and some brasses. It will be remembered that with d.-c. straight polarity it is possible to secure penetration while with reversed polarity a dispersal of the oxides is achieved. With a. c. we have, in effect, a current continually changing from straight to reversed polarity. Therefore, with a. c. it is possible to secure continuous penetration and weld without flux. Using argon and a standard welding transformer supplemented with a high-frequency oscillator welds may be made in all positions.

It should be pointed out here that it is common practice to use standard welding transformers and connect to them, externally, the high-frequency oscillator.

Some equipment is available with the oscillator built in. These oscillators are for the most part of the spark gap type and operate on frequencies in the range of radio frequencies. In consequence thereof the Federal Communications Commission has found that these oscillators may interfere with radio transmission. Much research effort is being directed toward correcting this situation.

When the tungsten arc operates on a. c., a d.-c. component[3] normally exists and tends to saturate the secondary of welding transformers. This d.-c. component has been found to be as much as 80 amp. when welding with 200 amp. a. c. The presence of this component leads to such undesirable characteristics as reduced penetration, requirement of greater flows of shielding gas and irregular shaped weld beads. It requires larger power leads to the transformer and reduces the output of the transformer by 30–40%. This effect may be minimized by connecting a 6-v. storage battery (or batteries) in series with the welding leads, with the positive terminal toward the electrode. Capacitors may be connected in series with the welding leads in which case they serve to block the d.-c. component completely. The value of capacitance to be employed is dependent upon the maximum current used.

While the standard welding transformer with the superimposed high-frequency pilot circuit offers one means of welding those metals with difficult oxide conditions, it will have been observed that it presents two problems, viz., (1) radio interference and (2) the presence of the d.-c. component. The solution to the first problem is under investigation and further will doubtless be subject to regulation. The second problem is, in some respects, more important because it influences weld quality. While it is true that welding may be performed with the d.-c. component present, it should be realized that recent research has shown that many of the unexplained irregularities in this type of weld have been traced to this component. The use of storage batteries as a corrective measure is at best a makeshift; the series capacitors cannot be employed with the standard transformers and high frequency.

Thus, it will be seen that the standard a.-c. welding equipment is not completely satisfactory for this process and that equipment specifically designed for the work is needed. Such a unit is available and consists of a transformer welder incorporating the features necessary to overcome the difficulties enumerated. The machine is designed to provide sufficient open circuit voltage to yield a stable arc with either helium or argon. Further the d.-c. component is completely blocked by series capacitors. For ease in striking the arc a short impulse of high-frequency current is provided but it is disconnected automatically once welding is started, thus minimizing or avoiding radio interference.

This balanced a.-c. arc welder is equipped with secondary taps providing 100 and 150 v. The former is generally used with argon, the latter with helium. These voltages, however, are not available until the arc is established. This feature is accomplished by means of a signal voltage of 25 or 35 v. which is "on" when welding is not in progress. When the electrode is touched to the work the controls of this machine operate to turn on shielding gas and cooling water. Then, as the electrode is slowly withdrawn, the high-frequency spark is established, the welding current starts and welding may then proceed. The duration of this high-frequency impulse is only three cycles, hence it does not create objectionable radio signals. Thus, with the series capacitors and these open circuit voltages, a stable arc is produced with balanced a. c. This has been found most desirable for welding the light metals. Welds with this type of equipment may be made in all positions with the assurance of highest quality. Either shielding gas may be used with this power source.

As a guide to manual welding with these several welding power sources Table 1 is provided. In addition to showing the currents for use with the different sizes of tungsten, it shows the sizes of gas cup orifices recommended. These currents may also be used with the carbon electrode, where applicable. The current values to be used on any given job will depend upon (1) the metals to be welded, (2) the equipment used, i.e., whether water cooled or not, (3) the size or mass of the pieces, (4) the use or omission of preheat, (5) the position of welding and (6) the skill of the operator.

Since the inert gas comprises one of the essential features of this process, its control and application are of the greatest importance. The amount of gas should be sufficient to cover adequately the molten metal, but it must be realized that excessive gas flows are of no advantage and may even be detrimental to the weld. However, it may be generally stated that long extensions of the tungsten, beyond the gas cup, as, for example, when welding in restricted areas, will require somewhat higher than normal flows. If strong air drafts cannot be corrected or avoided then here, too, higher gas flows may be necessary. Insufficient gas coverage will be generally manifested by sputtering of the arc and the deposit of a dirty black scum over the weld in the case of aluminum. It should be observed here that these conditions may also be caused by contaminated electrodes, moisture in the arc, dirty base metal and, on occasion, a poorly adjusted spark gap on the high-frequency oscillator when it is used. Of course, the tungsten must be centered in the gas cup and the cup must be checked to make certain that the orifice has not been obstructed by accumulations of spatter and dirt.

While the inert-gas-shielded arc-welding process is simple in principle, it has been found necessary to provide certain equipment and auxiliary features to insure consistent, satisfactory results. The holder for the tungsten electrode must also provide for conveying the inert gas to the gas nozzle. Further, when currents above approximately 150 amp. are used it becomes necessary to resort to water cooling both for the holder itself and the welding leads, to keep the physical dimensions within reasonable limits. The use of water cooled welding lead permits the use of much lighter copper

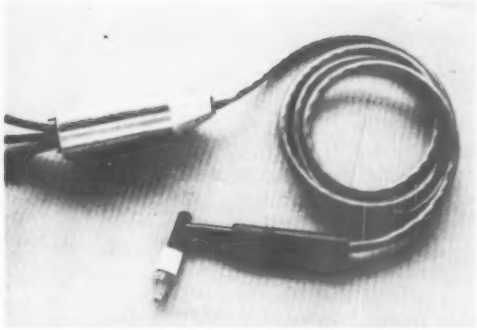


Fig. 2 Manual water-cooled holder and connector block for inert-gas-shielded arc welding

conductors than those conventionally employed for equivalent current in metal arc welding. A typical water cooled holder capable of accommodating electrodes up to $\frac{1}{4}$ in. diam. and having current capacities of 475-amp. d.-c. straight polarity or 425-amp. a. c. is shown in Fig. 2. This holder is also insulated for the high-frequency current. Figure 3 illustrates a holder designed for mechanized welding operations at currents of 800-amp. d.-c. straight polarity, 600-amp. a. c.

In inert-gas arc welding, one of the critical elements is the flow of the inert gas. Conventional regulators which merely indicate delivery pressure do not provide any measure of gas flow. Therefore, it is necessary to employ the metering or flow-type regulator which shows, continuously, the rate of gas flow. With this type of regulator it is possible to set the precise value of gas flow needed for the work.

Since the shielding gas is relatively expensive it is important to see that it is not wasted. However, it is equally important that the flow of gas be maintained after welding stops for a period long enough to ensure cooling of the electrode. If this is not done the hot electrode will become oxidized, from the air, resulting in a spongy end which will be unsatisfactory for welding. A simple method of achieving this end is to use a gas saver, connecting the inert gas through it. The other gas passage of the device may be used for cooling water, particularly if water costs are high. This control of afterflow of inert gas may also be accomplished automatically with the control panel discussed later, or the special balanced a.-c. transformer.

Ordinary rubber and fabric welding hose is not satisfactory for conveying helium since this gas will diffuse through the hose, and further air will enter from the outside. This condition may be demonstrated by immersing the hose in water and noting the bubbles arising. For conducting this gas it is better to use a plastic hose (Tygon has proved acceptable). Small diameter plastic hose may be used to line existing rubber hose lines or new, larger, heavy-walled plastic hoses may be employed.

Since water cooling is essential to the performance of the special cable used, in the holder lead, it is important to ensure an adequate flow and provide means of signaling should this flow be interrupted. In plants with old pipes in the water system it is a wise precaution to install a filter before connecting a holder. This will help to keep rust and sediment out of the fine passages of the holder. For signaling a failure of the water supply a flow switch should be placed in the water line. This flow switch may be connected in either the inlet or the outlet sides of the water circuit, but preferably in the outlet.

The oscillator, if used with a.-c. welding power source as previously described, should be connected to the holder with leads as short as possible as this will assist in avoiding leakage of the high-frequency current.

The spacing of the electrodes on the spark gap varies with different makes but in general it may be stated that the spacing should be as small as possible, consistent with good starting and welding. If the spacing is

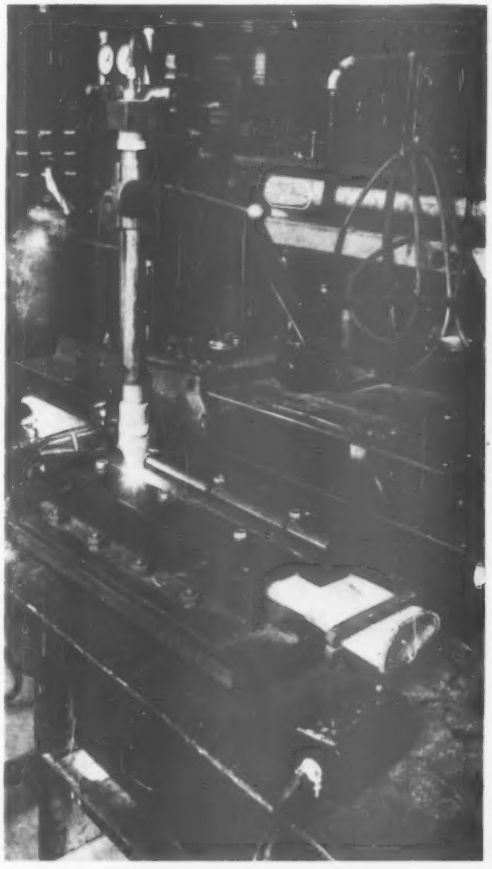


Fig. 3 Machine holder and universal positioner mounted on a travel carriage

too great it will cause breakdown of the insulation and excessive radiation. This gap clearance should be checked at least once a month and more often if welding conditions indicate a necessity therefor. The need for adjusting the gap will be manifested by an irregular sputtering of the arc and the failure to secure a uniform white band adjacent to the edge of the bead, particularly on aluminum. The source of the current for the oscillator is usually a 110-v. lighting circuit as distinguished from the 220- or 440-v. power source for the welding transformer.

If necessary, the high-frequency oscillator may be controlled from a foot switch or switch mounted on the handle of the holder. This arrangement is desirable when welding must be performed in a tank or an elevated structure, under which conditions the high-frequency current should not be on until everything is ready to start welding. Either type of switch is wired into the 110 v. supply to the oscillator. By controlling the high frequency with these switches it is possible to stop welding current when the high frequency is shut off. Breaking the arc by withdrawing the electrode with the high frequency on, gives a long arc which may result in hollow craters and lead to crater cracks. Craters can be filled properly by using the high frequencing to start and stop the arc intermittently while filling the crater.

In order to facilitate handling, much of this control equipment has been assembled into a control panel, Fig. 4, which provides for:

1. Control of gas flow after welding is stopped, by means of a solenoid valve and a time delay relay; a hand valve for flow regulation is also provided;
2. Starting and breaking the arc by means of a welding current contactor;
3. Control of circulating water by means of a hand valve and a flow switch, this latter being connected to the welding current contactor;
4. Control of the high frequency so that it is on only when welding.

This control panel may be employed with either a.-c. or d.-c. welding power sources, with or without high frequency and for manual, mechanized or automatic welding. For balanced a. c., as supplied by the Heliweld Bumblebee transformer, these features are incorporated in the unit.

It will have been observed that in all of this equipment there are many connections for water, gas, etc. These connections must be made up tightly for all the reasons usually advanced. In the case of inert gas connections one further reason exists, viz., a loose hose connection may not only permit the escape of gas but it may also tend to draw in air. Such air mixed with the inert gas would tend to defeat the purpose of the inert gas.

While the definition of the process indicated that the electrode is not consumed, it must be appreciated that there will be some loss of tungsten. This will occur

Fig. 4 Control panel

chiefly through contamination of the electrode end by dipping it in the molten base metal. Once the arc is established and operating at the correct voltage and current, the consumption of tungsten will be negligible. The actual amounts will be found to be least with d.-c. straight polarity, next with a. c. and high frequency and greatest with d.-c. reversed polarity. If the end of the tungsten becomes contaminated, it should be broken off or ground to a fresh end as otherwise the fouled end will melt off and drop in the puddle.

STAINLESS STEEL

The general group of alloys designated as stainless steels are very successfully welded by the inert-gas arc-welding processes, particularly in thicknesses below about $^{3}/_{16}$ in. Square groove butt joints up to $^{1}/_{16}$ in. thick, when properly jigged, may be welded without filler metal and still have reinforcement at both the top and the root; in the other joint types filler metal, without any coating or flux, may be added in a manner similar to that used in gas and carbon arc welding. Welds may be made in all positions, i.e., flat, horizontal, vertical and overhead. Reinforcement at the face of the weld can be maintained at very low values and, therefore, finishing of welds is a very simple and economical operation. As is common with all the applications of this process, flux is unnecessary.

The precautions necessary when welding the stainless steels by other methods, exist for these processes also. Thus, with the straight chrome steels, the necessity for pre- and postheating must be observed and followed. It should be noted that the straight chrome steels are more commonly employed in the range of thicknesses for which metal arc welding is more suitable. The chrome-nickel alloys, however, are used extensively in the lighter gages, and it is in this field that the inert-gas arc-welding processes find especial success. The problems of carbide precipitation exist with this method, in the unstabilized varieties of stainless steels. Since welding speeds are appreciably higher, the zone of carbide precipitation will be narrower and somewhat closer to the weld. Carbide precipitation may be avoided by the use of stainless steel with columbium or titanium as stabilizers. Since there is no metal transfer across the

arc, titanium may be used as the stabilizer without fear of loss as is the case with metal arc welding. Mechanical properties of inert-gas arc welds in stainless steels will, in general, match the properties of the base metal in the annealed state.

The power sources and shielding gases for the welding of stainless steels may be listed in the following order of preference: d.-c. straight polarity with helium; d.-c. straight polarity with argon. Tungsten is the electrode material generally used but carbon may also be used under some circumstances.

For thicknesses greater than 20 gage, d.-c. straight polarity with helium and a tungsten electrode provides the best welding conditions for both manual and automatic welding. The intense heat of the arc under these conditions makes possible the highest welding speeds. If the parts are rigidly held in a jig so that movement under welding heat is controlled, then the molten metal at the weld is caused to upset thus providing reinforcement at both the root and the face. Such weld reinforcement, however, is small when compared to that obtained with other methods and, in consequence, the work of finishing is greatly reduced; for some classes of service finishing is unnecessary. There is no slag to remove from the welds and such slight discoloration as does occur may be removed by light power brushing.

Argon may be substituted for helium in the above arrangements and substantially the same results secured with the exception of speed and penetration. The advantage in speed with helium is valuable principally in mechanized and automatic welding. Another advantage in increased speed is the lessening of distortion. While maximum welding speeds cannot be secured in manual welding, the factor of increased penetration with helium is important.

If a carbon is substituted for the tungsten electrode in the former conditions (d. c., straight polarity and argon), the arc will be found particularly suited for manual welding of thin gage (20 gage and lighter) stainless steel sheets. Here the relatively "colder arc" slows down welding speed and avoids burning through this very thin metal. Further, with the carbon arc, starting will be readily accomplished. To those who raise the question of carbon pickup by the stainless steel from the electrode, it can only be stated that a large manufacturer of stainless food equipment has not encountered this difficulty. Strauss tests conducted on these welds have failed to disclose contamination.

While most of the standard joint designs are suitable for this process, best results are obtained without filler metal, particularly in automatic welding. This means that the square groove butt joint is the most frequently used. In some cases filler metal can be provided by inserting a strip of the base metal edgewise in the joint. A little experimentation will assist in determining the width and placement of this filler metal strip to secure a satisfactory weld. For other types of joints manually welded, filler metal may be introduced but it must be appreciated that this will slow down welding speed. Under these conditions it is sometimes more practical to resort to metal arc welding, especially for fillet welds.

Arc starting which may be difficult, particularly with low currents, may be facilitated by using a short impulse of high-frequency current for automatic welding, or by the use of a carbon block on which the arc is struck. The use of a carbon electrode also assists in arc starting. If a carbon block is used for starting, care must be exercised to avoid long contact of the tungsten electrode as this will tend to foul the end causing the formation of a large ball. The presence of such a ball will create unstable arc conditions.

In the actual welding operation it should be obvious that the highest welding speed, consistent with job requirements, will yield best results on this metal. Further, the use of the smallest electrode size which will carry welding current for the desired penetration will result in the narrowest weld zone. Control of these same factors will also tend to minimize distortion.

In welding butt joints it is desirable to afford some protection at the root of the weld. Where the root is accessible, a jet of inert gas may be employed or a small hydrogen flame may be burned to secure the protection. Backing bars, plain or grooved, made of copper will also afford good protection. However, with backing bars the space between the sheets and the backing strips must be kept small, the amount depending upon the thickness, in order to achieve optimum protection. Protection at the root of the weld is very important in automatic welding.

The use of jigs in the welding of stainless steel by this process is very important particularly on square groove butt joints without filler metal. This requires that the jigs be of substantial construction capable of exerting sufficient force to prevent movement of the sheets under welding heat. Back-up bars should be incorporated in the jig structure for the reasons enumerated above. In addition to these functions performed by the jig, they will also serve to minimize distortion on these thin gages of stainless steel.

In manual welding where the number of pieces or the shape of the part precludes the use of jigs, tack welding should be employed to preserve alignment. It is sometimes advantageous to use the carbon electrode for tack welding, completing the welding with the tungsten electrode.

In the manual welding of stainless steel by this process, either the forehand or the backhand techniques as defined for gas welding may be used. Generally speaking, the conditions surrounding the job will dictate the direction of welding. Excessive puddling or remelting of the weld deposit should be avoided since this may lead to the creation of a large weld pool with the possibility of contamination.

Occasionally in welding stainless steel, a soot-like deposit will be encountered alongside the welds. This is more likely to occur with helium. This deposit, a purely surface condition, is not harmful and may be readily wiped or brushed off.

Contamination of the inert gas is caused by external sources and is not generally associated with the purity

Fig. 5 Stainless steel milk pails—partially welded to left; finished pail to right

of the gas in the cylinder. The most common contaminant is the surrounding atmosphere which may be drawn into the inert gas stream through faulty connections or improper manipulation of the holder.

Table 2, is offered as a guide for the manual welding of the indicated thickness of stainless steel with direct current, straight polarity and either argon or helium as the shielding gas.

One example of commercial production with the inert-gas arc process is shown in Figs. 5 and 6. Figure 5 pictures a welded, partially completed milking machine pail at the left, while a completed unit is at the right. Figure 6 illustrates the setup and jigging for welding the circumferential seam using a machine Heliweld Holder. Alignment of the arc with the joint

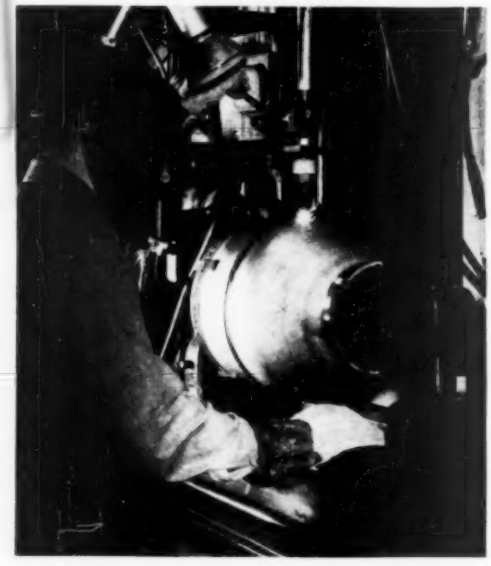


Fig. 6 Welding a circumferential seam with machine holder—note guide roller to right of arc

Table 2—Manual Welding Stainless Steel

		Argon		Helium	
Material thickness, in.	*Diameter of tungsten, in.*	*Current range, d. c.-s. p., amp.*	*Argon gas flow, cfh.*	*Current range, d. c.-s. p., amp.*	*Helium gas flow, cfh.*
0.031	0.040	25–40	6–7	18–30	6–10
0.050	1/16	80–225	6–10	50–180	8–12
0.0625	1/16	80–250	6–10	60–210	10–14
0.078	3/32	80–300	6–10	60–225	10–16
0.125	1/8	150–375	8–12	100–300	10–20

NOTE: Flows measured in liters per minute may be converted to cubic feet per hour by using the following equation which gives approximate values: Cubic feet per hour = 2× (Liters per minute)

is accomplished by means of the wheel (riding the groove) seen to the right of the gas nozzle.

In Fig. 7, to the left, is shown a deep drawn stainless steel cup (about 2 3/4 in. diam. by 4 1/2 in. long) and the

Fig. 7 Stainless steel container—parts to left, welded unit at right

stamped disk closure for the open end. The completely automatically welded assembly is pictured to the right in Fig. 7. Figure 8 illustrates the method of jigging these parts and the application of the Heliweld Automatic Head to the operation. The cup is 0.045 in. thick, while the head is 0.065 in. thick; these two pieces meet in a corner joint, the diameter of the stamping matching the outside diameter of the cup. Using d.-c. straight polarity at 18 v. (arc voltage), 65 amp. (1/16-in. tungsten electrode) and 10 liters per minute of helium, welding was accomplished at a speed of 36 in. per minute.

Examples of extremely fine Type 308 stainless steel performed manually with this process are shown in Fig. 9. Part 1, to the left, shows a capillary tube (1/16-in. O. D. x 0.020-in. I. D.) which is welded to a 3/16-in. O. D. x 3/32-in. I. D. tubes wedged to fit the capillary. This welding is performed with a 1/8-in. carbon electrode using 20 amp. on d.-c. straight polarity and 8 cfh. The assembly of the 3/16-in. tube and capillary is next welded into a plug inserted in a 1-in. O. D. x 0.085-in. wall tube; the other end is sealed with a solid plug. This welding requires 45 amp. on the 1/8-in. carbon elec-

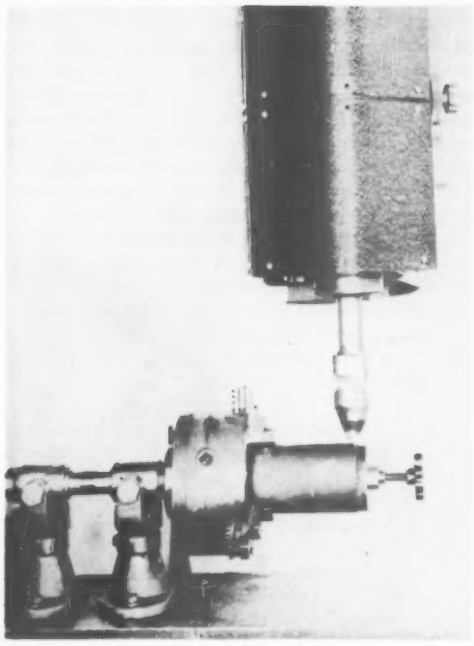


Fig. 8 Setup for welding parts shown in Fig. 7, using automatic head

trode with 10 cfh of helium. Part 2, to the right, is substantially the same type of assembly, except that the coil is substituted for the straight tube. These assemblies are tested at 500 psi.

ALUMINUM

Aluminum is one of the metals that is welded very successfully by the inert-gas-shielded arc process, principally because it eliminates the use of flux, so necessary with other welding techniques. Welds made by this process will show high mechanical properties and will consistently pass X-ray examination.

Of all the possible sources of welding power only a. c. offers all the desirable features. Early in the development of this process d.-c. straight polarity was used but required a flux consisting of equal parts of aluminum welding and brazing fluxes mixed with alcohol, to secure satisfactory results. It was observed earlier in the discussion of reversed polarity that this current arrangement had the property of dispersing oxides particularly those of aluminum. Unfortunately, reversed polarity is unsuited for welding aluminum because of the reduced current capacity of electrodes under this condition. However, in a. c. we have, in effect, straight polarity on one side of the a.-c. wave and reversed polarity on the other, and these occur 60 times a sec. Further, with alternating current the electrode current capacity is reasonably high and the oxide film is dispersed, thereby producing clean welds. Thus, it is possible to weld aluminum without flux using a. c.

A tungsten a.-c. arc is usually hard to start and difficult to maintain with standard transformers because of the changing nature of the current. Using standard welding transformers, this may be overcome by introducing the high-frequency pilot circuit which assists in starting and maintaining the arc as the current passes through zero. With this welding power arrangement, experience indicates that argon is the best gas to use. The disadvantages of the method have been covered earlier under the discussion of radio interference, d.-c. component and lowered transformer capacity.

Another means of overcoming the inherent difficulties of the a.-c. arc is to use a transformer, which provides balanced a. c. with two values of open circuit voltage, viz., 150 and 100 v. This equipment has been discussed earlier. Either argon or helium can be used with the balanced a. c. Helium, particularly in automatic welding, offers advantages in increased speed and lower currents.

The purity of the gases used for welding aluminum is very important. Argon should be not less than 99.8 ratio (argon to nitrogen) purity for consistent results. Water vapor must be avoided as it will lead to inferior welds. Nitrogen in excessive amounts may cause a black scum deposit on the weld; this, however, does not appear to affect the weld itself, as exographs are sound. Helium should be 99.5% purity, which is the value now being commercially supplied. Again, water vapor should be avoided.

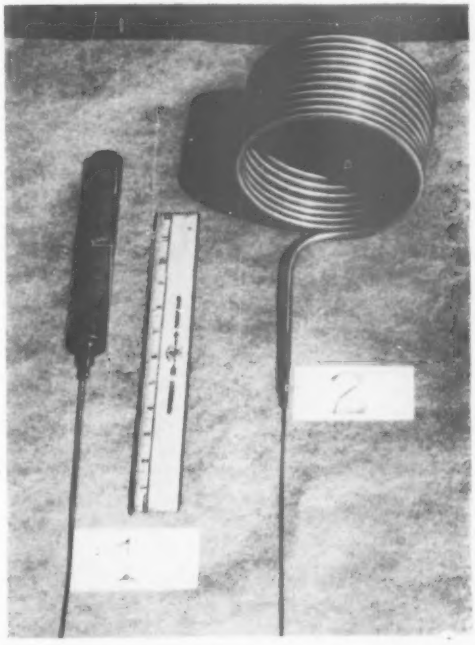


Fig. 9 Assembly of Type 308 stainless steel capillary tubes with larger elements: manually welded

The amount and velocity of the inert gas delivered to the welding zone is important because it influences the quality of the finished weld. Sufficient gas must be available to shield the electrode, the arc and the molten metal. Too great a flow or velocity of the gas may create an undesirable welding condition. This condition will be reflected in weld metal porosity and poor appearance. The orifice of the gas cap, Table 1, must be large enough to ensure the proper flow of low velocity gas.

While the inert-gas welding processes are capable of welding aluminum without flux, this must not be construed as meaning that cleaning prior to welding may be ignored. The minimum cleaning operation should be degreasing.

Normally, compositions such as 2S, 3S and 52S will not exhibit difficult oxide conditions, while the higher, weldable alloys will. Where difficult oxide conditions are encountered, they should be treated in the usual manner either by mechanical cleaning or chemical cleaning. Cleaning should not precede welding by too long a period of time as this will permit re-oxidation.

The standard joint designs are applicable for inert-gas arc welding of aluminum. For thicknesses up to about $^{5}/_{32}$ in. the square groove butt joint is generally suitable and grooved joints for greater thicknesses. Where welding may be performed from both sides, material up to $^{1}/_{4}$ in. thick may be welded without beveling. Butt joints may employ backing structures, preferably of stainless steel. Filler metal, without coating or flux, will be necessary for most butt joints over about $^{1}/_{16}$ in. because of the tendency of the molten pool to sag. This latter fact limits the use of automatic welding on butt joints unless a suitable wire feeding device for filler metal may be secured. Lap and tee-joints may be welded with fillet welds and, in the case of the former, the upper sheet may be melted to provide the filler metal.

The introduction of filler metal in the manual welding of aluminum is something of a problem because of the high heat conductivity of this metal and its strong tendency to oxidize. If the filler rod is maintained in continuous contact with the arc and puddle it will be found that it tends to soften and melt well up the rod outside the protective envelope of the inert gas. This naturally leads to oxidation of the rod surface and when it reaches the weld puddle will slow up welding (as the operator must manipulate the arc to remove the oxide) and may introduce oxide. One technique for overcoming this is to apply the rod intermittently—almost drop by drop. This calls for a slight backing up of the tungsten while the end of the rod is dipped in the molten metal. In this method it is a wise precaution not to withdraw the rod from the protective envelope of gas as this again would permit oxidation.

In production work, jigs and fixtures for the maintenance of contours, shape and dimensional accuracy as well as control of distortion will be found helpful. If welding is performed without filler metal, the edges of butt joints must be accurately fitted and held in close, metal to metal, alignment for best results. Similarly, lap joints welded without filler metal must also be maintained in metal-to-metal contact.

Welding aluminum by this process, using either of the power arrangements listed previously, is essentially the same as other welding techniques. Recommended currents and electrode sizes for several thicknesses are provided in Table 3; these data are provided for both the a. c. with high frequency (and therefore with d.-c. component) and the balanced a.-c. circuits. Manual welding may be performed in all positions; vertical welding, coming down, gives good penetration and is recommended on thicknesses up to $^{3}/_{16}$ in.; above this, vertical welding upwards is preferred. Filler metal should be selected on the same basis as is employed for welding with the older processes. Filler metal should be cleaned with as much care as base metal. Overheating of the metal must be avoided, as this creates a large area of molten metal which extends beyond the gas shield and results in oxidation with all its attendant ills.

While welding of the heat-treated alloys is not generally recommended, reports of experimental work in progress indicate that the best results acheived so far are obtained with this process. In those alloys exhibiting crack sensitivity (52S and 61S), it is important to fill all craters and avoid highly restrained joints. It is difficult to secure exact color matching of weld with parent metal, nevertheless, these welds will take anodizing and similar treatments.

An extremely interesting practical application of this process in a maintenance operation is shown in Fig. 10.

Table 3—Manual Welding of Aluminum

Metal thickness, in.	*Tungsten electrode Size in.*	*Alternating current with high frequency and d.-c. component*		*Balanced alternating current*			
				Helium		*Argon*	
		Current range, amp.	*Argon flow, c.f.h.*	*Current range, amp.*	*Helium flow, c.f.h.*	*Current range, amp.*	*Argon flow, c.f.h.*
$^{1}/_{16}$	0.040	40–75	10–15	20–60	10–15	–85	10–15
	$^{1}/_{16}$						
$^{3}/_{32}$	$^{1}/_{16}$	75–125	14–18	30–100	12–16	60–130	14–18
	$^{3}/_{32}$						
$^{1}/_{8}$	$^{3}/_{32}$	100–170	15–18	60–175	15–20	80–200	15–18
	$^{1}/_{8}$						
$^{3}/_{16}$	$^{1}/_{8}$	125–225	15–20	80–240	18–25	110–300	15–20
	$^{3}/_{16}$						
$^{1}/_{4}$	$^{3}/_{16}$	200–300	15–25	...	24–30	200–410	15–25
	$^{1}/_{4}$						

This tank is 10 ft. in diameter, 16 ft. long and fabricated of $^3/_8$-in. thick 2S aluminum; it is used for the storage of peroxide. The bottom ring of these tanks had to be replaced and was removed by mechanical means. The new ring was aligned by means of a circular strap (visible in Figs. 10 and 11) provided with slotted holes through which tack welds 4–5 in. long were made. Welding was performed with the manual water-cooled holder using $^3/_{16}$-in. tungsten electrode, standard a.-c. welding transformer with the superimposed high-frequency stabilizing current. Welding current of 260–300 amp. was used. Argon flow of 25 l. per minute (about 50 cfh.) was necessarily high, since work was performed out of doors. About 12 lb. of 2S welding rod was required to fill the 90° single vee-groove butt joint ($^1/_8$-in. land) and provide a backing bead. Welding, as may be seen in Fig. 11, was performed in approximately the vertical position.

Fig. 10 Aluminum (2S) tank, 10 ft. in diameter, 16 ft. long and $^3/_8$ in. thick, set up on rolls for welding of new bottom section

Fig. 11 Manual welding of joint between new and old sections of tank, see Fig. 10. Note clamp for alignment

Figure 12 shows two permanent mold castings used in an assembly of a special gasoline tank. The assembly welded at both the external and internal intersections, is shown in Fig. 13. This material, which averages about $^1/_8$ in. thickness, is manually welded using the balanced a.-c. transformer, a $^1/_8$-in. tungsten electrode and 125 amp. with an argon flow of 15 l. per minute (30 cfh.).

COPPER AND COPPER BASE ALLOYS

Copper

Commercially pure copper is welded with success by the inert-gas arc-welding process. However, the limita-

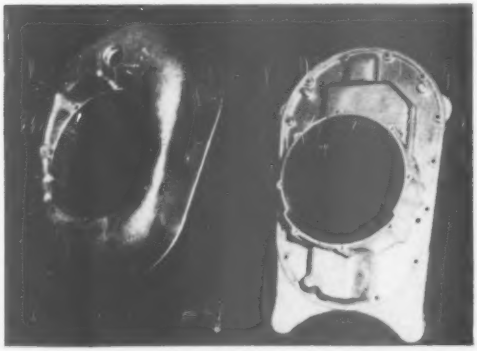


Fig. 12 Permanent mold castings used in fabrication of gasoline tank

Fig. 13 Welded assembly of gasoline tank

tions which exist for other welding methods, obtain in this case also. Thus, deoxidized or oxygen-free copper may be welded and joint strengths equaling that of the annealed base metal will be secured; electrolytic or tough pitch copper, while it may be fused, will be found to yield very low strengths (of the order of 12,000 psi.) due to segregation of the copper oxide inevitably present in these types.

Direct current, straight polarity, with tungsten and helium as the shielding gas, provides the best results. Argon may also be employed, but the "colder arc" will be found to be less satisfactory because of the high heat conductivity of the copper. Preheating will not, in general, be necessary on thicknesses up to 1/4 in. and on small sections. On thicknesses greater than 1/4 in. and on large masses, preheating will permit faster welding speeds and insure sounder welds. Flux is, of course, unnecessary. Large cast copper sections must be preheated to about 600° F. and this preheat maintained continuously during welding to prevent formation of residual stresses.

There appears to be a tendency for welds in copper, by this process, to exhibit porosity. However, this is not invariably the case and there does not appear to be a complete explanation available at present. Another source reported cracking adjacent to the weld without identifying the base metal type. Cracking sometimes occurs when welding the electrolytic or tough pitch types but should not be encountered with deoxidized copper.

The production of rotors for fractional horsepower motors has been facilitated by the introduction of this process of welding. Figure 14, to the left, illustrates an assembled rotor with the copper end plates and projecting copper bars coined for temporary holding. This part is then preheated and set upon a rotating table under a machine Heliweld Holder. Welding is accomplished in this semiautomatic setup, Fig. 15, using d.-c. straight polarity at 150 amp. on a 1/8-in. tungsten electrode with helium flow at 7 l. per minute. Preheating serves to increase the over-all speed of welding. Two welds are necessary, one on each end, to complete the rotors, which are produced at a rate of about one each minute.

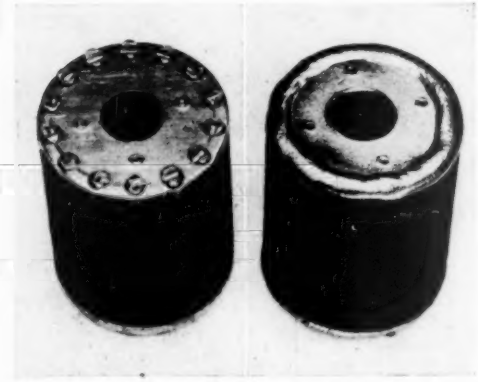


Fig. 14 Rotor assembly for fractional horsepower motors—preliminary mechanical assembly to left, welded unit at right

Fig. 15 Setup for welding rotors—preheating shown at left, welding at the right

Copper Base Alloys

Of the numerous copper base alloys only a relatively few have been reported upon in connection with their welding by this process, but enough have been welded to indicate that this method is eminently suited for the copper base alloys. Of this group the silicon bronzes, aluminum bronzes, manganese bronzes and some brasses have yielded satisfactory results. It should be noted that if the alloy is in the cold-worked (hardened) state, the heat of welding will produce annealed zones on each side of the weld and, therefore, the joint strength, as-welded, will be equal only to the annealed strength of the base metal.

Silicon Bronze. This group of alloys generally contains about 3% silicon and 96–97% copper with various other small additions. These metals are best welded with d. c., straight polarity and helium or argon, although a. c. with high frequency and argon may be used in thicknesses up to about 3/8 in. Heavy sections are regularly welded with d. c., straight polarity using filler metal of the same analysis. This silicon bronze filler metal, either plain or tin coated, frequently has been used for joining sheet steel, particularly tin coated and galvanized sheet. This same braze welding technique may be employed with d. c., straight polarity and argon even with the tin-coated rods and excellent results secured.

Manganese Bronze. Large manganese bronze castings have been successfully welded with balanced a. c. and helium or argon, or standard a.-c. transformers with high frequency and argon. For light sections of such castings, localized preheat is sufficient while larger areas and heavier sections require general preheating. Aluminum bronze rods (bare) provide good

filler metal but imperfect color match. For closer color match it is best to cast rods of the same analysis as the base metal.

Brass. In the field of brasses, manual welding has been performed on an architectural bronze of the basic 70% Cu. – 30% Zn. composition with an addition of about 2.5% Pb. Ordinarily, this would be considered unweldable with such a high lead content. However, using d. c. straight polarity and argon, this was successfully welded. It was also welded with a. c., high frequency and argon. Color match at the weld will not be exact due to the fact that the lead "sweats out."

MAGNESIUM

Magnesium is probably the first metal which was successfully welded by the inert-gas arc process. It played an important part in the salvage of castings and fabrication of sheet parts of magnesium. The fact that flux was unnecessary eliminated one of the doubts always attendant upon gas welding of magnesium, i.e., the complete elimination of flux residue. If flux is not entirely removed, it will ultimately attack the magnesium and weaken the structure.

Magnesium may be welded with d.-c. reversed polarity and either helium or argon; or it may be welded with a. c., high frequency and argon. The d.-c. reversed-polarity tungsten arc in helium produces a smoother, neater bead than the arc with the same electrical conditions but using argon. The use of a. c. and high frequency with argon yields excellent results as good with helium and d.-c. reversed polarity. On some magnesium alloys a. c. appears to give best results.

Cleaning is very important in the welding of magnesium, since failure to observe this instruction is very likely to cause incomplete penetration and porosity. First, remove all oil and grease with carbon tetrachloride or similar solvent. Next, clean the top, bottom and edges adjacent to the weld with abrasive cloth or steel wool; do not touch the cleaned surfaces with the hands. The filler rod must also be cleaned with steel wool. Cleaning should not precede welding by too long a time as surfaces will re-oxidize.

Joint designs are substantially the same as for other forms of welding. For metal up to $^1/_8$ or $^5/_{32}$ in. the square groove butt joint is satisfactory, since the arc readily penetrates these thicknesses. For greater thicknesses, either the single or the double-vee groove butt joint may be used. The included angle of the vee should be 90–120°. Single and double bevel tee-joints may be employed on plates intersecting in a "T." Grooved backing structures may be employed to control the amount of root penetration.

STEEL

At present, in the light of available knowledge, the welding of rimmed steel does not appear to be a uniformly successful operation. In explanation, it may be stated that the intensely localized application of heat and the rapid welding speeds which characterize this process seem to cause such rapid freezing of the molten metal that the gases evolved do not have time to escape, and, in consequence, are trapped forming porosity. In some cases, moderate success has been achieved with d.-c. straight polarity and either shielding gas, but the mechanical properties of such welds are low. In other cases, where porosity has been excessive, it has been attributed to residual oxygen in the steel.

Killed steels, particularly those treated with aluminum, may be readily welded with the inert-gas arc process. The tungsten electrode with either helium or argon has proved successful. The application is, however, limited to gage metal thicknesses since the other arc-welding processes offer more practical and economical approaches to the problems of welding heavy steel sections. If filler metal is to be added in a weld made by this process, it, too, should be of the killed variety.

SILVER

Silver — sterling and commercially pure — has been successfully welded by the inert-gas arc-welding process using d.-c. straight polarity and either helium or argon. Some porosity may be experienced when using either gas, but, in general, the results are satisfactory. In common with most other welding processes, the weld will exhibit large grain size.

One of the principal applications of this method is in the joining of special silver pipe used in certain chemical processes. Another use is for the overlaying of silver on steel to make, in effect, silver clad steel.

NICKEL AND NICKEL ALLOYS

Commercially pure nickel and Monel are welded with only moderate success with this process. In the case of nickel, porosity is the major difficulty. Monel in some special variations of this fundamental analysis welds satisfactorily, whereas the normal type develops cracks and porosity. However, in some automatic welding applications, the introduction of an oxyacetylene preheating flame has been found to eliminate porosity on the standard analysis of Monel. Any of the power and gas combinations may be used, but d.-c. straight polarity, is best.

Inconel has been successfully welded using d.-c. straight polarity and helium. This alloy is currently being welded mechanically to form small diameter tubing.

OTHER METALS

Many other metals have been successfully welded by this process; however, such uses are limited either be-

cause the metal has but a restricted field of use or the need for the welded product does not exist. A typical example of this is the pure metal titanium, now produced on a laboratory scale, only. This is very successfully welded with balanced a. c. and helium.

An alloy steel containing 4% silicon is used extensively for transformer cores, etc. To facilitate continuous rolling of this metal into thin sheets, strips are welded into continuous lengths. For this purpose, d.-c. straight polarity and either helium or argon are employed. Both semiautomatic and fully automatic equipment are used.

Lead, in its various analyses, is welded by this method and excellent results secured. Welding power is d.-c. straight polarity; the shielding gas, helium; and the electrode, tungsten. The shielding gas serves an additional purpose here in that it suppresses the lead fumes which may be annoying and sometimes dangerous.

CONCLUSION

The many new advantages and properties of this inert-gas-shielded arc-welding process commend it to industry for wide use. However, these very advantages carry with them the necessity for greater care and control in the application of the process if optimum results are to be obtained. Thus, the elimination of chemical fluxes does not mean that all cleaning may be omitted; and the achievement of the high welding speeds characteristic of this process may not be enjoyed unless joints are accurately and carefully fitted. In short, these advantages may be secured only if good welding practices are observed.

When difficulties are encountered, it is quite natural for those who are new to the process to suspect the purity of the inert gas as being the cause of the trouble. Practical experience has shown that of all the possible sources of trouble, this is the least likely to be involved and particularly in so far as purity in the cylinder is concerned. Improper hoses and connections are more likely to create contamination of the gas and should be checked. Another factor is the control of gas flow. The inert gas must flow before welding starts to ensure purging of the lines. It must also continue after welding to cool the tungsten and avoid oxidation of the end of the electrode. Welding power source is one of the more frequent sources of trouble. With a. c., using standard transformers and the high-frequency pilot-circuit, the adjustment of the oscillator spark gaps is a common cause of welding difficulties. Joint fit-up may also contribute to poor welding. Sloppy fit-up most certainly will yield poor welds. Then, of course, there is the problem of operator skill. While this process is similar in many respects to the older processes, there is sufficient difference to require those learning the new technique to discard preconceived notions and approach the work with an open mind.

The inert-gas-shielded arc-welding process is new when compared with the established welding methods. Its inherent advantages, however, have established it as one of the more important current techniques. This very newness carries the further implication that many advances may be anticipated in view of the extensive research in progress. Thus the data herein presented may well be rendered obsolete when new data are published. A case in point is the preliminary information on the properties and possibilities of higher purity helium now undergoing tests.

ACKNOWLEDGMENT

The authors wish to express their appreciation for the cooperation and assistance afforded them by W. A. Mays and W. A. Jenkins of the U. S. Bureau of Mines, Helium Plant, Amarillo, Tex.

References

1. Gibson, G. J., The Inert-Gas-Shielded Arc-Welding Process, The Welding Journal, **27** (5), Research Suppl., 281-s to 294-s (1947).
2. Wassell, F. A., Characteristics of Welding Arcs on Aluminum in Atmospheres of Helium and Argon, *Ibid.*, **24** (10), Research Suppl., 487-s to 493-s (1944).
3. Gibson, G. J., and Rothschild, G. R., The Effect of D.-C. Component in A.-C. Inert-Gas Arc Welding of Aluminum. Paper was presented at Annual Meeting of the American Welding Society, Oct. 24–29, 1948, and published in The Welding Journal, **28** (10), Research Suppl., 496-s to 501-s.

Current Welding Literature

Agricultural Machinery, Welding. Farm Equipment Remade, E. J. Koop. Welding Engr., vol. 33, no. 5 (May 1948), pp. 54–55, 64.

Airplane Propellers, Manufacture. Controlled Welding and Heating . . Important Factors in Fabrication of Hollow Steel Aircraft Propellers, A. Q. Smith. Steel, vol. 123, no. 21 (Nov. 22, 1948), pp. 100, 103–104.

Alloys. Stellite in Mining Industry, B. G. MacKenzie. Can. Min. J., vol. 69, no. 8 (Aug. 1948), pp. 71–74.

Bridges, Steel. Construction of Welded Bridges in Europe, M. A. Goelzer. Civ. Engrs. Rev. (Sept. 1948), pp. 287–291.

Containers, Steel. Welding Aircraft Storage Containers, R. K. Kewley. Iron Age, vol. 162, no. 21 (Nov. 18, 1948), pp. 102–105.

Dams, Concrete, Repair. Dam Gets Face Lifting, H. W. Young. Welding Engr., vol. 33, no. 5 (May 1948), pp. 46–48, 51.

Electric Motors. Reconditioning Worn Traction Motor Housings, D. M. Laflin. Ry. Mech. Engr., vol. 122, no. 9 (Sept. 1948), pp. 507–509, 512.

Electric Transformers, Welded Attachment. Elimination of Gaskets on Underground Submersible Transformers, C. P. Xenis. Edison Elec. Inst—Bul., vol. 16, no. 11 (Nov. 1948), pp. 383–384, 386.

Electric Welding, Arc. Inert-Arc Welding of Hard-to-Weld Metals, M. J. Conway. Machy. (N. Y.), vol. 55, no. 4 (Dec. 1948), pp. 148–154.

Electric Welding, Arc, Sheet Metal. Welding for Porcelain Enameling, L. K. Stringham. Iron Age, vol. 162, no. 25 (Dec. 16, 1948), pp. 90–94.

Electric Welding Machines, Maintenance and Repair. How to Care for Transformer Type a.-c. Arc Welders, J. R. Morrill. Factory Mgmt. & Maintenance, vol. 106, no. 11 (Nov. 1948), pp. 120–123.

Electric Welding Machines, Manufacture. Welders on Assembly Line, T. B. Jefferson. Welding Engr., vol. 33, no. 5 (May 1948), pp. 56–57.

Electric Welding Machines, Portable. Standardized Guns Cut Welding Costs, R. Heath. Tool Engr., vol. 21, no. 3 (Sept. 1948), pp. 36.

(*Continued on page 207*)

Welding Alloy Steels for High-Temperature Service

The peculiar conditions prevailing in high-temperature oil and gas processing require special design consideration and special alloys

by M. E. Holmberg

INTRODUCTION

The oil industry has constantly demanded better materials of construction and has always used the properties of available materials to the utmost. Repeatedly it has been limited in the oil and gas it could produce or the products it could make by the properties of the steels and other materials used in equipment. In order to reduce the number of failures and to permit the use of more severe operating conditions, the oil industry is always looking for better materials; and, as they have been developed, has been quick to put them into service. It is only natural, therefore, that the oil industry has become one of the big users of alloys and welding. If it were not for the use of alloys and welding, many of the present day operations, especially with respect to processing, would be impossible.

Where metals are used under severe conditions, numerous problems and failures are encountered. By studying these failures, much can be learned, as a failure in service is in effect a test to destruction. Complete information concerning the characteristics of materials under all the conditions encountered in high temperature services is not available. It therefore is especially important that studies be made of failures in materials used in high temperature service. This paper is based principally on the study of failures in welded alloy structures and most of the problems and failures referred to were associated with high temperature service. It is limited to processing equipment such as used in gasoline plants and refineries and deals mostly with piping.

DESIGN

The use of back-up rings is common practice in welding piping and many codes and specifications make their use mandatory. Undercuts and cracks at the root of the weld, poor penetration and other common defects are frequently found in welds made with back-up rings. Thousands of miles of pipe lines have been successfully welded without back-up rings, which are objectionable because they interfere with the running of scrapers to clean out the lines. Carbon steel piping welded without back-up rings has been entirely satisfactory in refinery and gasoline plants. Because of extensive successful experience in welding steel piping for oil, gas, steam and water service, without back-up rings, the use of back-up rings for welding alloy piping was not considered necessary.

Hydrocarbon gas that remains relatively dormant "cracks" at high temperatures with the formation of carbon. This carbon frequently exerts sufficient pressure to distort metal. The pressure exerted by carbon which forms when hydrocarbon gases are heated to high temperatures was illustrated by the failure of a transfer line heat exchanger. The gases to be cracked were preheated by a heat exchanger which also cooled the cracked gases. Each unit of the exchanger consisted of a 4-in. O.D. tube passing through a 6-in O.D. shell section. The end of one unit is shown in Fig. 1. The hot

Fig. 1 One end of a transfer line heat exchanger which failed when the hot gases, passing through the center tube, heated the gases that remained dormant in the head and caused the formation of carbon. The carbon exerted sufficient pressure to deform the head and to squeeze the center tube in two as shown in Fig. 2

M. E. Holmberg is with the Phillips Petroleum Company, Bartlesville, Okla.

This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

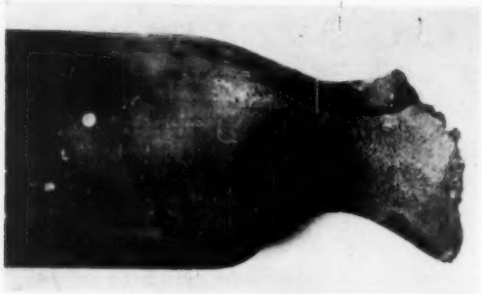


Fig. 2 Inside tube, which was squeezed in two by carbon that formed inside of exchanger head shown in Fig. 1

gases passed through the tube and the gases to be cracked were preheated by passing in the opposite direction through the shell. Several such exchangers were connected in series. At the hottest end the gases that collected in the head decomposed with the formation of carbon, which exerted enough pressure to squeeze the inner tube in two (see Fig. 2) and to expand the head and shell. To prevent the occurrence of such failures it was necessary to design equipment so as to eliminate pockets in which gas could collect and "crack." In the exchanger referred to, the shell nozzle was moved to the end of the head to eliminate the "dead end" in which the gas could remain dormant long enough to "crack."

Freedom from root bead cracks and incomplete penetration was essential, as carbon would form in even very minute cracks and could wedge the metal apart and cause complete failure. Minor root bead defects, which in most services would not have been serious, were responsible for numerous failures because of carbon formation. A failure resulting from incomplete fusion along one edge of a weld between an 18–8 and a 25–20 tube is shown in Figure 3. The manner in which the carbon tears the metal apart at cracks is illustrated in Figs. 4 and 5. Trouble of this type was aggravated in salvaging used tubes by the necessity of welding carburized tubes and tubes of varying wall thicknesses. Even though it might have been considered desirable to use back-up rings, their use would have been unsatisfactory because carbon would have formed and torn them loose. In welding the austenitic steels, difficulty was constantly experienced with root bead, crater, and micro cracks. Some of these fine cracks are evident in Fig. 5. Such cracks are still a common occurrence and micro fissuring is an important consideration when making austenitic welds.

Fig. 3 Failure in weld between 18–8 and 25–20 tubes. Failure resulted from expansion of carbon that formed in crack caused by poor fusion along one edge of weld

AUSTENITIC STEELS

The use of high alloys, such as the "stainless steels,"

Fig. 4 Inside surface of weld that failed as a result of incomplete penetration. Carbon formed in the crack and tore the metal loose

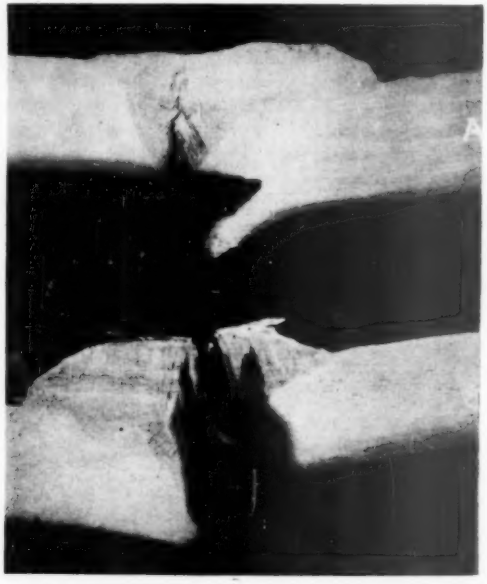


Fig. 5 Cross sections of weld between new and salvaged 25 Cr–20 Ni tubes showing manner in which carbon tears metal apart. Note numerous cracks in weld metal and carburized metal at lower surfaces and at cracks

is often associated with corrosion; but corrosion resistance is only one of the reasons for using alloys. The "stainless steels", such as 18–8 and 25–20, are used in many refinery and gasoline plant applications—not because of their corrosion resistance to the fluids being processed, but because of their excellent high temperature oxidation resistance and physical properties. The literature is full of references and recommendations that stabilized alloys should be used if they are to be welded or exposed to temperatures between 800 °F. and 1600° F. Where corrosion is not a factor and the austenitic alloys are used solely because of their high temperature properties, they need not be stabilized even though they are welded and exposed to temperatures above 800° F.

Stabilization depends either upon the carbides being combined with the stabilizing element, usually columbium or titanium, or upon the spheroidization of carbides upon exposure to elevated temperatures and the diffusion of chromium so as to eliminate the depletion of chromium which occurs when the carbides are precipitated. Many of the services in gasoline plants and refineries are such that even the austenitic steels become carburized. Carburized cases $^1/_8$-in. deep have frequently been observed and analyses have shown carbon contents approaching 3% in the cases developed in 18–8 and 25–20 tubes. Carburized surfaces are evident in Fig. 5. It is obvious that the stabilizing elements do not remain effective when the carbon content increases to many times that of the stabilizing element. Because neither corrosion nor intergranular cracking developed in many applications of nonstabilized austenitic alloys in high temperature service where carburization occurred, it also became the practice to use the nonstabilized austenitic steels for all high temperature applications where corrosion was not a factor. Such applications have been successful.

For intergranular corrosion to occur, it appears that an electrolyte must be present. Since an electrolyte cannot exist at elevated temperatures, intergranular corrosion does not develop even though carbide precipitation has taken place. For example, nonstabilized 18–8 has performed satisfactorily in a welded superheater that produces 1200° F. steam-air mixture. Where the non-stabilized alloys are used in high temperature service, care should be taken that corrosive waters are not used for hydrostatic testing and that corrosion does not occur during shut down periods as a result of condensation and the formation of an electrolyte. This precaution with respect to condensation during shut down periods may be necessary for only a limited time, as operating temperatures are often high enough to stabilize the metal by spheroidization of the carbides and diffusion of the chromium. Intergranular oxidation does occur at elevated temperatures and has frequently been observed in both chemically and heat stabilized austenitic steels, and, of course, can proceed without the presence of an electrolyte.

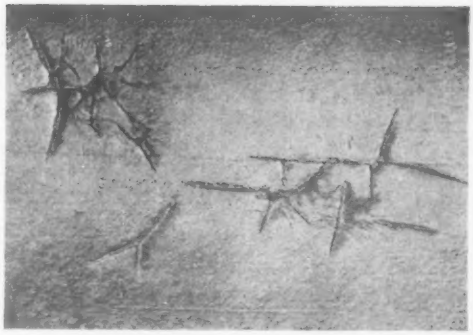


Fig. 7 Cracks in carburized case on inside surface of tubes. These cracks were caused by hitting the outside surface with a ball peen hammer to check the piping for thin spots. The cracks have partially opened up. Such cracks quickly develop into holes completely through the tube

Where carburization occurs, cracks are easily formed in the carburized case. Such cracks should be avoided as they can quickly develop into complete failures. The carburized surface has practically no ductility and cracks with very little deformation. This is illustrated in Figure 6 which shows cracks on the surface of a tensile test coupon cut from a carburized 18–8 tube. It is a common practice to check piping for thin spots by hammering with a ball peen hammer. This practice had to be discontinued as hammer blows on the outside of piping would crack the carburized case on the inside. Cracks caused by hammer blows are shown in Fig. 7. It was frequently necessary to weld carburized 18–8 and 25–20. This was successfully done without cracking the case, provided the welds were preheated and too much current was not used in welding. Figure 8 shows cracks near the weld in the case on the inside surface of an 18–8

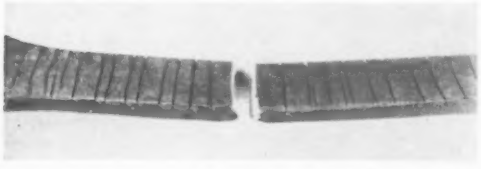


Fig. 6 Tensile test made in specimen cut from carburized 18–8-Cb tube

Fig. 8 Cracks in carburized case adjacent to weld in carburized 18–8-Cb tube

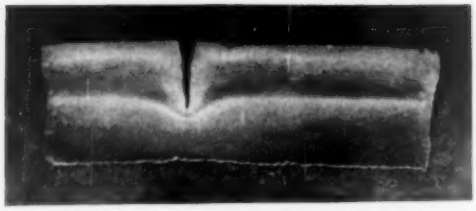


Fig. 9 Etched cross section of crack in heavily Carburized 18-8 tube. Note progressive nature of crack as indicated by variation in depth of carburization

tube that was welded with excessive current and without preheating.

There was reason to believe that some cracks, which developed on the inside surface of heavily carburized tubes, were caused by stresses set up by differences in the coefficients of expansion of the base material and the carburized surface. Data on thermal properties of 18–8 with varying carbon content were not available; therefore, an experiment was devised to determine whether there is a difference in rate of thermal expansion of the carburized and non-carburized sides of an 18–8 tube. A 12 in. long by $1^1/_4$ in. wide strip was cut from a $5^1/_2$ in. O.D. × $^1/_4$ in. wall carburized tube which was carburized approximately half way across the wall thickness. The specimen was straight when cold. It was placed in a small furnace and heated slowly and uniformly to 1190° F. while resting on one edge. The specimen bowed during heating with the carburized surface on the inside of the bend. After cooling, it was slightly curved in the opposite direction. The carburized specimen and another non-carburized 18-8 specimen of the same size, which was cut from a new tube, were placed together on edge and carefully heated with a torch to a uniform red heat (maximum measured with a thermocouple was 1200° F.). The carburized specimen deflected $^3/_8$ in. at the center with the carburized surface the inside of the bow, while the non-carburized specimen remained straight, as shown in Fig. 10. The curvature was apparent with only slight heating. Upon cooling, a slight (approximately $^1/_{16}$ in.) bow in the opposite direction remained.

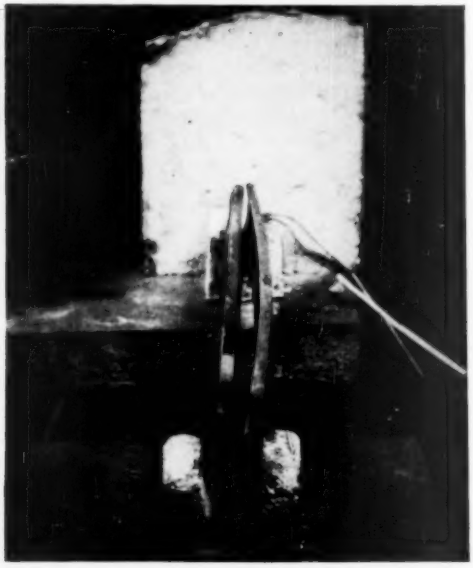


Fig. 10 Bow in carburized 18-8 tube when heated to 1200° F. to demonstrate difference in coefficient of expansion between carburized and non-carburized 18-8

The austenitic steels seldom are ductile at high temperatures and generally fail with very little elongation. When carbon formed in gas cracking furnaces and eroded the tubes so that they became very thin high stresses and creep rates developed, with the result that 18–8 and 25–20 tubes showed considerable ductility before failing. By measuring the circumference of the tubes, the ductility could be readily checked and elongations up to 14% were measured in tubes that were originally $5^1/_2$ inches O.D. The welds, however, which are essentially castings, were less ductile at the operating temperatures and failed with much less creep than the wrought austenitic tubes. If welds were present at locations where considerable creep occurred, transverse cracks across the welds developed, as shown in Fig. 11.

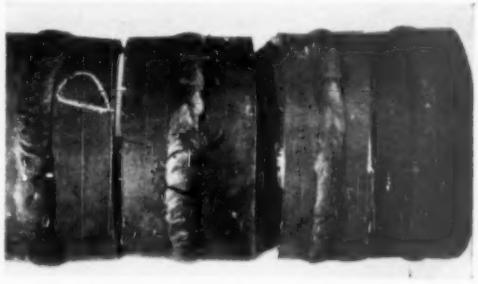


Fig. 11 25 Cr–20 Ni welds in 18–8 tubes. Failures occurred in approximately 2500 hr. because of the poor ductility in the weld metal when excessive creep occurred

FERRITIC ALLOYS

The chrome-molybdenum steels for still tubes were developed because of a need for steels resistant to corrosion at high temperatures when handling crude oils containing sulphur. The best known of these steels is the 5% chrome–$^1/_2$% molybdenum steel. The chrome-molybdenum steels containing more than 1% chromium are very air hardening, and for many years the welding of these steels was avoided. They were threaded or rolled into headers and return bends, and, because it was necessary to disassemble the units at frequent intervals in order to remove coke, mechanical joints were desirable and there was not much demand that these air hardening steels be welded.

Corrosion and erosion were often most severe at the ends of the still tubes with the result that large quantities of worn tubes accumulated which could be salvaged

if a new end could be welded on. Many such tubes have been salvaged using a welding procedure consisting of preheating to 400–600° F., welding with 5-chrome-molybdenum rod, and keeping the weld above 400° F. until it could be heat treated. The heat treatment was essentially a tempering treatment and consisted of heating to 1325–1375° F. and air cooling. This same procedure has proved satisfactory in the fabrication of piping and small vessels such as heat exchangers.

The other chrome-molybdenum steels were welded with the same procedure. Except on large construction jobs, where special welding rods were justified, the chrome-molybdenum steels containing less than 5% were welded with 5-chrome-molybdenum rod. During the war when all types of rods were not available, even 7-chrome-molybdenum and 9-chrome-molybdenum were frequently welded with 5-chrome-molybdenum rod.

When 9-chrome-molybdenum steel was welded with the above procedure it was found that the heat treatment was not effective. At first it was thought mistakes had been made in measuring temperatures, but this was not the case. Further investigation developed that the transformation temperature of 9-chrome-molybdenum steel on cooling is below 400° F., with the result that the weld and heat-affected zone remained austenitic and was not tempered. By letting the weld cool to 150° F. before tempering, transformation takes place and the weld can be tempered by heating to 1325–1375° F.

Where it is impossible to heat treat chrome-molybdenum welds, these steels are welded with the austenitic rod, 25 chrome–20 nickel. In such cases, the practice is to preheat to 400 to 600° F. and to keep the weld in this temperature range until welding is completed. Welding the chrome-molybdenum steels with 25 chrome–20 nickel is much faster and simpler as heat treatment can be eliminated. During the war, in order to save time and manpower, the practice of welding the chrome-molybdenum steels with austenitic rods became increasingly common. There are now many such welds that have given complete satisfaction in both new construction and in salvaged still tubes.

The ferritic steels should not always be welded with austenitic rods. Where welds in high temperature service will be exposed to frequent shut downs or to severe cyclic changes in temperature, the ferritic steels should be welded with ferritic rods, so as to eliminate the thermal stresses that otherwise develop from using a weld metal with a significant difference in coefficient of thermal expansion from that of the base metal.

A large installation of process equipment was made with 27% chrome tubing assembled with thousands of welds. The service was such that it was considered desirable to make the welds as strong as possible. The first beads which would come in contact with the fluid being processed were made with 27-chrome 4-nickel rods and the welds were completed with 25-chrome 20-nickel. Most of the equipment was subjected to sudden temperature changes twice an hour between approximately 950 and 1350° F. The balance of the equipment

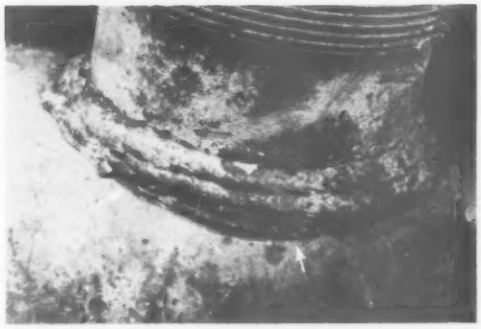


Fig. 12 Crack in 12-chrome tube at edge of 25 Cr–20 Ni weld. Such cracks develop when ferritic steels are welded with austenitic rods and subjected to frequent changes in temperature

operated uniformly at similar temperatures. Within a short time after being put into service, cracks started to develop in the 27-chrome steel at the edges of the 25 chrome–20 nickel welds that were in the cyclic temperature service. These cracks were attributed to the stresses set up as a result of the differences in coefficient of expansion between 27-chrome and 25-chrome 20-nickel steels. This interpretation was confirmed when the size of the plant was increased and the 25 chrome-20 nickel welds were replaced in the new equipment with 7-chrome-molybdenum welds. In the latter installation cracks never developed at the edges of the welds even though the 27-chrome steel became very brittle in service. Similar cracks (see Fig. 12) developed in 12-chrome (Type 405 steel) headers welded with 25 chrome–20 nickel and subjected to approximately the same temperature changes. Simple butt welds made with 25–20 in ferritic steels do not develop cracks unless subjected to very severe temperature changes. Cracks are more likely to form at the edges of fillet welds; probably because a change in section is usually associated with fillet welds and the thermal stresses are liable to be higher. If operating temperatures are uniform, cracks do not develop at the edge of fillet welds; but, if the equipment is subject to frequent shutdowns or cyclic changes in temperature, cracks will probably develop, especially where fillet welds are at large changes in section. The cracks are not due to welding. When cracks have been found in air hardening steels at the edge of austenitic welds after being exposed to cyclic temperature changes, it has been found that the cracks do not necessarily follow the heat-affected zone. This is illustrated in Fig. 13 which shows the cross section of a reinforcement pad attached to a 5-chrome-molybdenum pipe with a 25–20 weld. Instead of following the heat affected zone, the cracks extended across the wall of the pipe.

The difference in the thermal coefficients of expansion between ferritic and austentic steels is important when it is necessary to weld these two types of steel together and use them in high temperature service. As shown

A-3719

Fig. 13 Cracks in 5 Cr-Mo pipe at the edge of a 25Cr-20Ni fillet weld used to attach a reinforcement pad. The piping was subjected to severe changes in temperature periodically, and failure developed because of thermal stresses resulting from changes in section and the difference in coefficient of expansion between the ferritic and autenitic metals. It should be noted that the cracks did not follow the heat-affected zone

in the preceding paragraph, failures can be expected if the equipment is exposed to changes in temperature.

Another point that should be considered in welding ferritic steels with austenitic rods is that the austenitic weld metal has a lower melting point than the ferritic steels. When using small diameter austenitic rods and depositing small beads in an effort to reduce the welding stresses, there is danger of not obtaining fusion with the higher melting point ferritic steel being welded.

OBSERVATIONS CONCERNING HIGH TEMPERATURE SERVICE

The expansion and contraction that takes place upon heating and cooling must be carefully considered in high temperature service. When it is necessary to use the austenitic steels, the effects of expansion and contraction are especially important, as the austenitic steels have a coefficient of thermal expansion almost one and a half times that of the ferritic steels, and, unless adequate provision is made, very high stresses will develop. Such stresses are likely to be concentrated at fillets, welds or notches. This stress concentration is especially serious because the austenitic steels are subject to stress cracking. Designs and assemblies are such that any stress concentration usually occurs at or adjacent to welds and the failures are often mistakenly attributed to welding. Figure 14 shows a failure at the edge of a weld between a butt-welding flange and a tube, all materials being 18–8-Cb. Cracks developed at the outside surface and failure took place after the equipment had been in service only 10 weeks and had been shut down and allowed to cool only a few times. Adequate provision had not been made for the expansion and contraction of the austenitic steel piping which operated at approximately 1200° F., and high bending stresses developed where it was flanged to a heat exchanger assembly. By setting the light heat exchangers on rollers so that they could be moved when the units were heated or cooled, the high stresses were eliminated and additional failures did not occur in approximately the seven years that the equipment remained in service. At other locations where adequate provision could not readily be made for expansion and contraction, it has been necessary to unbolt certain flange connections when the equipment is shut down and allowed to cool. Numerous failures take place because the effects of expansion and contraction have not been adequately considered. Another example is the failure of a steam superheater. The 18–8 tubes were supported by 18–8 straps. The tubes were tack welded to these straps and the restriction to free movement of the hot tubes was sufficient to cause stress cracking at the tack welds. By removing the tack welds so that the tubes could expand and contract freely, additional failures were eliminated.

Stress concentration is often aggravated in austenitic steels by the cracks caused by intergranular oxidation, which seems to progress most rapidly at the areas of high stress. Intergranular oxidation was found to have taken place in the highly stressed areas on the outside surface adjacent to the weld between the 18–8-Cb butt-welding flange and tube illustrated in Fig. 14.

The austenitic steels are hot short; that is, they show very little ductility at elevated temperatures. This characteristic is recognized by those who must hot roll and form these steels, but is not recognized by many fabricators and users. Simply because the austenitic steels have high tensile and creep strengths at elevated temperatures, it is often assumed that they are less likely to fail. This is not necessarily the case. Where deformation is likely to occur in the hot short range of approximately 1100 to 1800° F., failures will develop very quickly. Such a failure is illustrated in Fig. 15

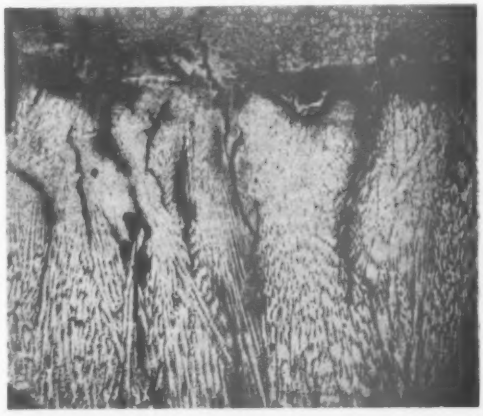
Fig. 14 Fracture at edge of weld between 18–8-Cb flange and tube, and caused by failure to make adequate provision for expansion and contraction

Fig. 15 Detail of cracks in a 25–20 tube that was heated locally and bent while hot

which shows cracks in a 25–20 tube that was heated locally with a torch and bent while hot. A cross section of this crack at 50 diam. magnification is shown in Fig. 16. The intergranular path of the crack is apparent and it should be noted that additional cracks have opened up along the grain boundaries of adjacent grains. Such microscopic intergranular cracks can be present without being detected at the surface by a simple visual examination. It is quite evident that a material subject to the formation of such cracks will fail when it is deformed in the hot short temperature range.

Austenitic weld metal, especially 25 chrome–20 nickel, is prone to crater crack and form microscopic fissures. This became quite evident in the services in which carbon formed and opened up minute defects and where carburization occurred. Many of the cracks were so small that they were not detected by visual examination, but where carbon formed, these small defects were opened up. This is illustrated in Fig. 5. Carburization also outlined cracks. Variations in the amount of carburization at cracks showed that some were present in the welds when put into service and that others formed in service. The type of cracks referred to are illustrated in Figure 17. The cracks formed during welding appear to be due to the development of high shrinkage stresses while the metal is in the hot short range. Another contributing cause is probably the effect of impurities that segregate at grain boundaries and weaken them at elevated temperatures. Any deformation while the welds are in the hot short range causes any cracks present to progress and will even open up new cracks. Micro fissuring is still a serious problem in austenitic welds and should be studied by the manufacturers of weld rods and others concerned with the welding of austenitic materials.

Fig. 16 Cross section of crack shown in Fig. 14. × 50



25× *Oxalic acid etch.* *E-1176*
Fig. 17 Micro fissures in 25Cr-20Ni weld. Carburization at some of the cracks should be noted

The effects of expansion and contraction, stress concentration, hot shortness, creep and creep rupture are important in high temperature service, but are much more important where cyclic temperature conditions exist. Where high temperatures are constant, creep may gradually reduce stress concentration, and cracks caused by hot shortness may not become apparent except after numerous shutdowns and may not become serious for years. Cyclic conditions, on the other hand, may subject the equipment to sufficient changes in stress to cause failure within a very short time. Failures that result from cyclic exposure to high and low temperatures are frequently referred to as "thermal fatigue failures." If the alternate stresses, associated with heating and cooling, occur while the material is in the hot short range, failures will develop quickly.

Thermal conductivity becomes an important factor where equipment is subject to very great and sudden changes in temperature. Poor thermal conductivity can result in great differences in temperature between

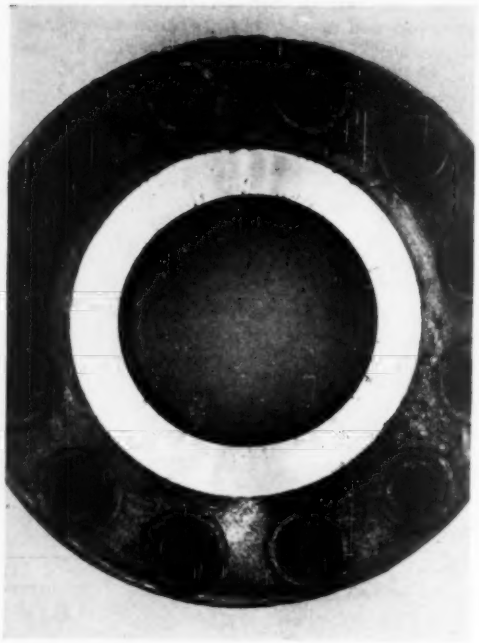


Fig. 18 No Cracks that developed at inside surface of an 18 Cr–12 flange after 10 days' service where the bore of the flange was subjected to sudden exposure to hot fluids

two surfaces or parts of a structure with the consequent development of high stresses. Welds have frequently been torn apart by such stresses. This phenomenon can perhaps be illustrated best by the cracks which developed in the bore of the austenitic (18 Cr–12 Ni) flange shown in Fig. 18. During one part of the cycle of the process in which this flange was used, the fluid passing through the flange was at a temperature of 1000° F. At the end of an eight-hour period a valve would close and the piping would cool to approximately 300° F. in about three hours. Approximately five hours later the valve would open quickly and the bore of the flange would again be exposed instantly to the 1000° F. fluid. The inside surface of the flange immediately became hot and would expand, but was restrained by most of the metal in the flange which was still relatively cool, with the result that the bore was, in effect, upset. As the entire flange became hot and expanded, the inside surface which was upset was put into tension and surface cracks developed. It should be noted that the inside surface was in tension while it was hot and in its weakest condition. High stresses develop upon the sudden application of heat to a structure because of the differences in temperatures between adjacent parts. Failures that result from the sudden application of heat or from quenching are often referred to as thermal shock failures.

The above 18 chrome–12 nickel flange which failed in only 10 days was bolted to a 5-chrome-molybdenum flange. Cracks did not develop in the lower strength ferritic steel. The reason for this was that lower stresses developed in the ferritic steel because of its higher thermal conductivity and lower coefficient of expansion. It has been observed repeatedly where massive or heavy sections are exposed to sudden applications of heat that the austenitic steels are subject to failure more quickly than the ferritic steels. The low thermal conductivity of the austenitic steel results in greater differences in temperature which in turn develops high stresses, and the stresses are further increased by the greater coefficient of expansion. The above 18 Cr-12-Ni flange was replaced with one made from 9-chrome-molybdenum steel, and it and the 5-chrome-molybdenum flange have given satisfactory service. Even though the ferritic steels are less likely to fail than the austenitic steels, when subjected to thermal shock, the ferritic steels will also fail if sufficiently great differences in temperature are developed. This is likely to occur at massive sections such as large flanges.

There are many problems associated with the use of alloys and welding for high temperature service. The processes in which the equipment is used often impose limitations with respect to design. The most important considerations, however, are the properties of the material and the change in properties between normal and elevated temperatures. Expansion and contraction resulting from heating and cooling must be taken into consideration in the original design. This is especially true of the austenitic steels which have high coefficients of expansion. Any deformation in the hot short range of materials, either during fabrication or in service, must be avoided. When equipment is exposed to frequent or sudden changes in temperature, failures are more likely to occur. Under such conditions the thermal conductivity and coefficient of thermal expansion must be carefully considered, especially where metals varying appreciably in these properties are used together, where sections of different thicknesses are assembled, and where very thick sections are involved.

Materials Joined by New Cold Welding Process

Strong welds in a number of nonferrous materials, particularly aluminum and copper, are possible with this simple cold welding method

by A. B. Sowter

A METHOD enabling metals to be welded at room temperature, called cold pressure welding, has recently been developed at the Research Laboratories of The General Electric Co., Ltd., England. The process is at present most suited to aluminum and its alloys and copper, although other metals can be cold welded. No heat need be applied in order to bring about a weld. Ductile metals are made to flow at room temperature by the application of sufficient pressure. By using a suitable arrangement of work pieces and dies, this pressure also brings the work surfaces into contact so that a genuine weld is made.

As stated, the most satisfactory applications of cold welding are with aluminum, aluminum alloys and copper. Other nonferrous metals are not likely to be welded by this method except in cases where strength is not important. However, some materials of different hardnesses can be joined. Thus, copper and nickel have been cold welded successfully to aluminum.

In welding aluminum alloys, not more than 3% of manganese or silicon can be tolerated if a satisfactory weld is to be made. Heat-treatable alloys, such as Duralumin, can be used in the soft condition and then allowed to harden in the usual way. Work hardening has the effect of improving the strength of the welded metal. Half-hard commercially pure aluminum, for example, reaches an ultimate tensile strength of 22,000 psi., or about twice its original strength.

The strength of any joint made by cold welding depends upon its shape. The least satisfactory design is a single straight joint where the stress is perpendicular to the length of the weld. Here the material is weakest immediately around the weld area, i.e., where the final thickness shared by the two pieces is about $1/4$ of the original total thickness. Since, however, the material has now work-hardened and is twice as strong as it was originally, the welded piece is now half as strong as the original single piece. By a carefully designed layout of welds in relation to stress, it is generally possible to arrange the joint without sacrificing any tensile strength. The top left-hand corner of Fig. 1 shows a tensile test specimen made up in 20 s.w.g. half-hard commercially pure aluminum where the weld is placed with its length parallel to the strip. Tensile failure occurred at 110-lb. load, by the pulling out of the weld area from one piece.

Strip joints and wire joints made by cold pressure welding have been tested for conductivity. A well proportioned joint in aluminum has a lower electrical resistance than an equivalent section of the unjointed material.

SURFACE PREPARATION

There are two important factors in the formation of a satisfactory weld. One of these is preparation of the surface, and the other is proper design of tools.

It is essential that the two surfaces, brought into contact between the dies, are entirely uncontaminated. Where aluminum is the metal to be welded, the oxide film covering the surface must be removed. It has been found that though this film is thin by ordinary standards its presence is quite sufficient to prevent welding. The problem of how to clean it away by a treatment that does not leave behind any of the debris arising from its removal formed a substantial part of the development work.

Chemical cleaning methods are unsuitable since they inevitably necessitate a washing of the surface in order to remove solvents. Reaction with the washing water would then immediately reform the protective layer, whose removal was being attempted. Cleaning methods such as filing and treatment with abrasives have proved unsuccessful, the first because some of the material which is removed is invariably re-embedded in the surface by later working, and the latter because, in addition, it leaves behind particles of the abrasive.

The method which is now adopted is to treat the surface with a power-driven rotary scratch-brush. A steel wire brush, running at a surface speed of about 3000 ft.

A. B. Sowter (Research Laboratories, of The General Electric Co., Ltd., England.

This article is reprinted from the November 1948 issue of Materials and Methods.

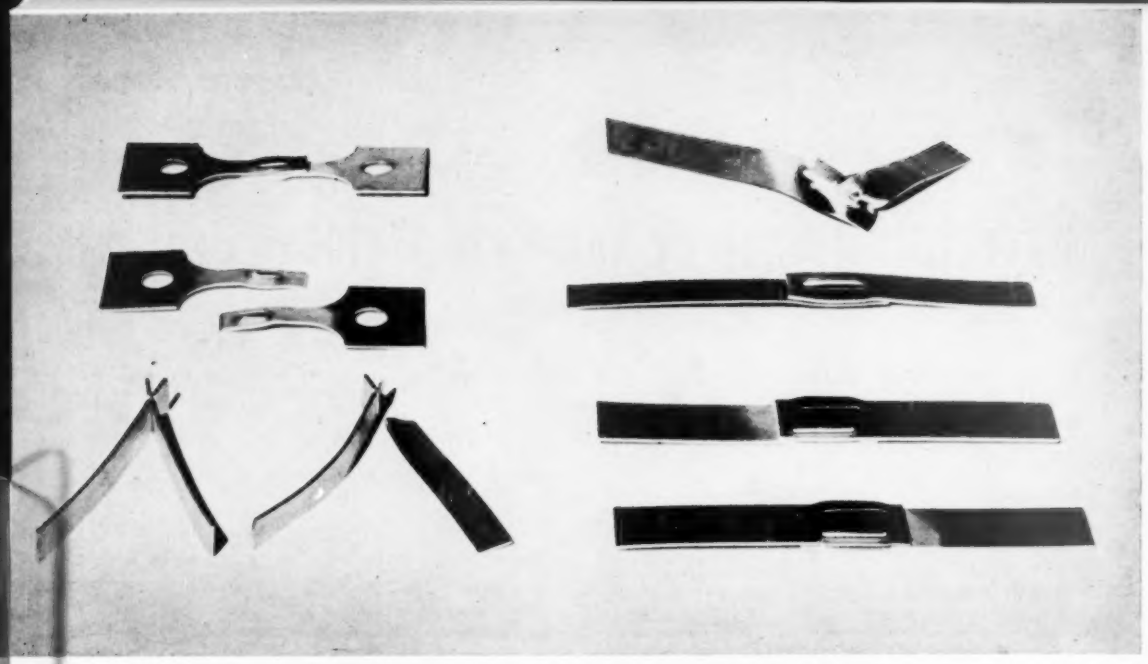


Fig. 1 Test specimens of aluminum welds made by the cold welding process

per minute, has been most commonly employed. The surface of the work must be held against the scratch-brush long enough to make the drag felt; this occurs when the steel wires break through the oxide film and seize onto the metal surface beneath. Small particles of the body metal and its coating of oxide are torn out and flung clear because of the high speed at which the wires are traveling. The hardness and gauge of the steel wire must be related to the dimensions of the work being treated, since it is obviously undesirable to weaken the structure by the removal of more metal than is absolutely essential for cleaning.

The surface of aluminum oxidizes immediately on exposure to the atmosphere, but some days elapse before the film reaches its final thickness. Once this relatively thick coating is removed and the metal is exposed, advantage must be taken of the time required for it to reform by welding immediately after cleaning. Satisfactory welds can be made several hours after the scratch-brushing process has been applied, provided that the cleaned surface has not meanwhile been contaminated by moisture or grease. Even the contamination conveyed by handling will invariably prevent a weld from forming.

DESIGN OF TOOLS

For successful cold welding the pressure must be applied over a comparatively narrow strip, so that the metal can flow away from the weld at both sides. This is achieved by applying the pressure between specially designed dies, and this imposes slight restrictions on the more complicated forms which these welds can take. The undesirable curvature resulting from a radial flow of metal can be seen in Fig. 2, which shows the results obtained with circular dies. When these welds were first attempted in the center of the strips, radial flow occurred and no welding took place. Identical circular indentations were then applied to the side of the strips and satisfactory welds resulted owing to the unidirec-

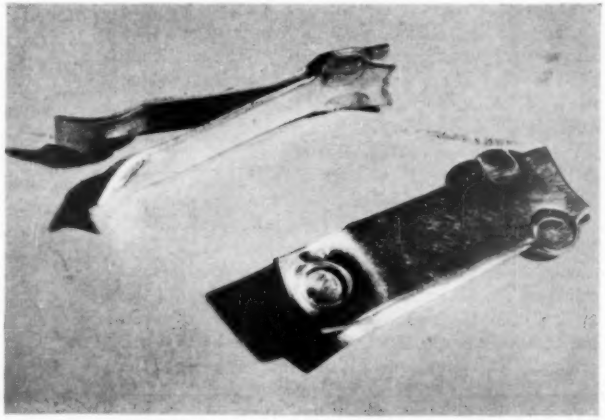


Fig. 2 Undesirable curvature results from a radial flow of metal such as results from circular dies

tional flow produced. Ring welds and other closed forms can, however, be made successfully, provided that there is sufficient free area within the weld to accommodate the excess of metal without undue buckling.

Figure of Merit of Materials That Can Be Cold Welded

Material	*Figure of Merit*
Super-Pure Aluminum	40
Commercially Pure Aluminum	About 30
DTD 346 (51S)	29
BA 60A (3S) (1¼% Mn)	20
Duralumin	20
Cadmium	16
Lead	16
Copper	14
Nickel	11
Zinc	8
Silver	6

The material used for making dies for commercially pure aluminum is usually mild steel, while on unhardened chromium-manganese tool steel is also satisfactory. These materials give no trouble with pickup of aluminum, a slight surface contamination, resembling a thin plating, being the only evidence of pickup occurring. It is possible that pickup may be troublesome if an unsuitable steel is used for welding rollers. A detailed list of such unsuitable materials cannot yet be given, but the present practice is to avoid tungsten and molybdenum steels. Where suitable die materials have been used, there is very little evidence of die wear. In many applications, however, it will be possible to counteract the effects of such wear by an occasional resetting of the die closure.

The pressures required for cold welding are only slightly above the flow of aluminum, in the region of 24,000 to 36,000 psi. That required for copper is from two to four times this value. The rate of application of the pressure does not appear to affect the strength of the final weld. Good welds can be made with tools giving either a slow squeeze or an impact.

As already seen, the shape of the tool is important. Where a rectangular form is used, the size of the rectangle depends on the gauge of the sheet being worked. Where symmetrical tools, working from both sides of the weld, are used, W, the length of the rectangle, is made equal to the gauge thickness, t; L, the length of the rectangle, must not be less than $5t$. Where it is desirable to keep one face free of indentation, a single tool is used in conjunction with a flat plate or anvil. In this case, W is increased to $\frac{1}{2}t$.

When cold welding materials of different hardness, in order to share the final thickness equally between the two materials, the width of the welding tool must be adjusted according to the hardness ratio. Thus, W for a tool in contact with aluminum against copper is increased to $2t$, since the hardness ratio of copper to aluminum is approximately 2:1 in the annealed condition.

The final gap between the tools, or between the tool and the anvil, may either be set by a stop which limits the closure of the press or by a shoulder on the tool. It is more advantageous to use the shouldered tool, since it restores the distortion produced by the actual welding process. Both plain and shouldered tools can be used for impact welding. The former, with a closely controlled blow such as that given by an automatic center punch, is used for welding gauge thicknesses of the order of 0.012 in. The latter, using a specially shaped punch and a hammer, can be employed for thickness of the order of 0.036 in.

The gap between the tools, or the tool and the anvil, is limited in order to prevent further penetration after the welding point has been reached. The minimum reduction in thickness required to ensure a satisfactory weld varies from metal to metal. The "figure of merit" used to classify metals, as regards their suitability for the process, is given by the ratio:

$$\frac{\text{Thickness of weld}}{\text{Twice thickness of original material } (T)} \times 100$$

The correct gap for the tool is therefore given by the "figure of merit," values of which are given in the accompanying table. For example, since the value for commercially pure aluminum is 30, the gap should be set at $30/100 \times T$, where T is the double thickness.

APPLICATIONS OF THE PROCESS

This cold welding process has already been used with success in a number of different applications. An example of a straight weld is shown in Fig. 3. This can be

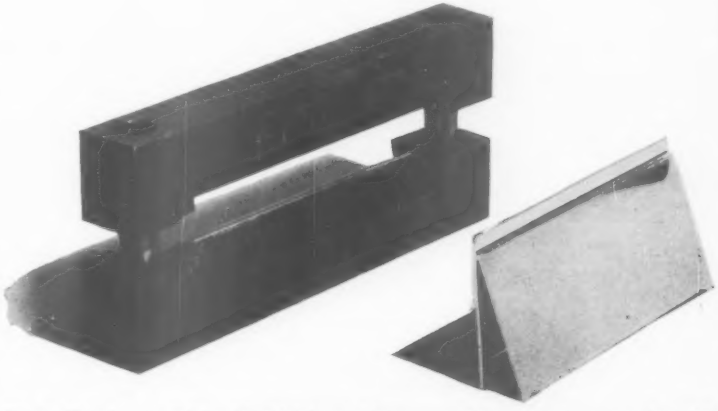


Fig. 3 Here is a straight weld which is used in commercial applications, together with the dies used

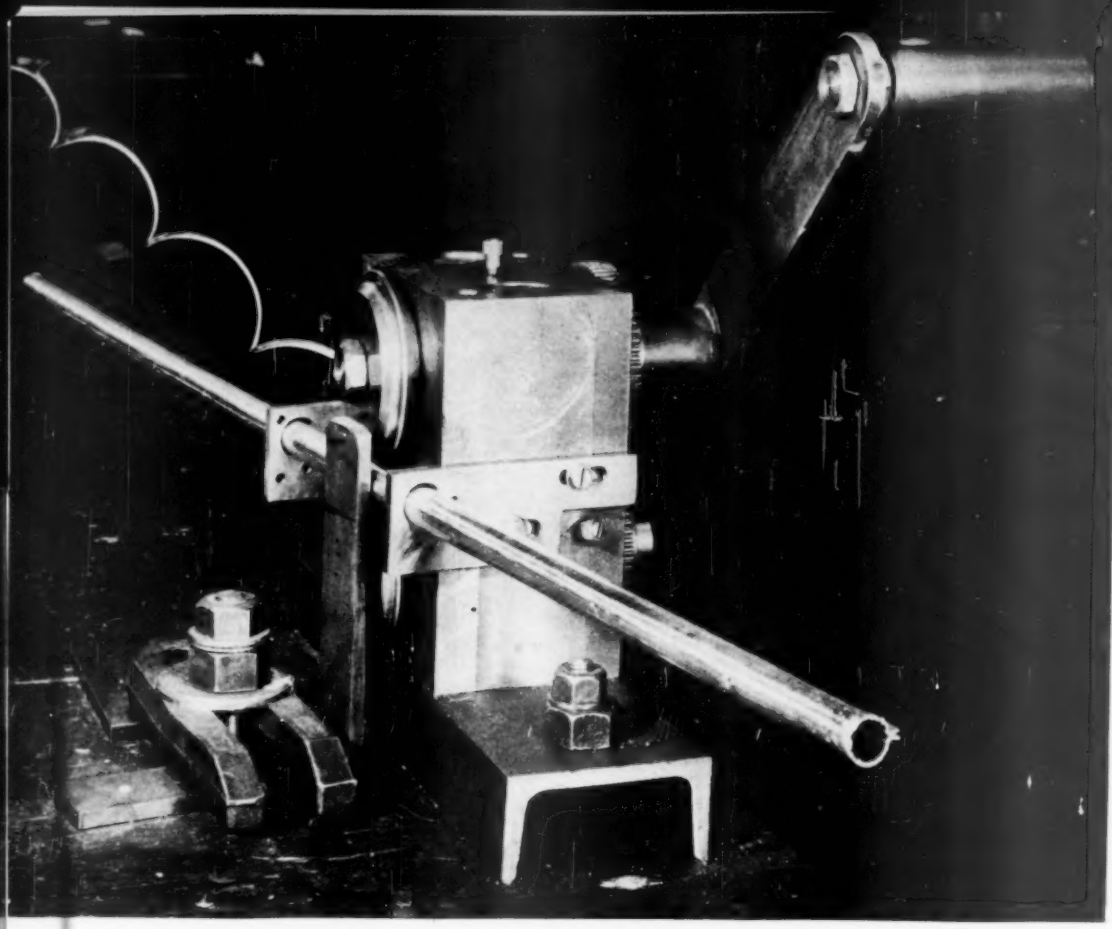


Fig. 4 Cold welded tube is trimmed to remove the metal flange formed by metal flow

used for box seams, for sealing tube ends, and for other forms of capped joint which are almost equivalent to butt welds. The ring weld already described can be used for joining a flanged tube to a plate for making hose connections, or two discs can be joined together to make an air pressure cell. The most important application of the continuous seamweld is for tubemaking. A machine has been constructed at the Research Laboratories of The General Electric Co., Ltd., in which the process of preforming, scratch-brushing, final forming, welding and trimming is carried out continuously and automatically. In addition a roller welding machine can be used to seal the edges of a folded section following a complicated outline. The free edges of a box-shaped section may also be seamed by rolling in such a machine.

Much interest in this process of cold welding has already been shown. Its many applications are obvious, and it offers a promising new joining method to those engaged on large-scale production, as well as to those in small workshops.

Hard Surfacing of Cast-Steel Propeller Blades

This paper deals with examination of hard-surfaced cast-steel propeller blades after service in salt water in both warm and cold climates

by K. B. Young, H. J. Nichols and M. J. Nolan

Abstract

The use of hard-surfacing alloys of the A.W.S. Group III (Co-Cr-W) type, primarily to combat corrosion, is fairly common. In such applications the factor of resistance to wear is usually of secondary importance. This paper reports on an examination of hard-surfaced cast-steel propeller blades after service in salt water in both warm and cold climates. Severe boundary line galvanic corrosion was detected with more advanced attack on the astern faces of the blades. Surface checking of the surfacing alloy had allowed salt water to penetrate to the steel base with consequent subsurface galvanic corrosion, notably at the junction line between two deposits of the alloy which had been deposited at different times and by different methods.

INTRODUCTION

MANGANESE bronze ship propeller blades for salt water service have long been standard equipment for naval and commercial craft. In peacetime there is a continuous search for cheaper, stronger and/or more durable materials for this application. In wartime, the huge shipbuilding programs far outstripped the capacity of suppliers of the manganese bronze propellers, and cast-steel blades were used on a variety of ships entering into widely varying types of service. In at least one case, the cast-steel propeller blades were surfaced with A.W.S. Group III (Co-Cr-W) type hard-surfacing alloys in an attempt to enhance service life by preventing, or at least retarding, cavitation. The authors recently were afforded an opportunity to examine blades so treated after fairly extensive service in both warm and cold sea water. The results of this examination are presented herein.

The vessel on which the coated steel blades were installed is a twin screw cable ship operating in the North Atlantic and in the West Indies. The ship averaged an estimated 40% of time at the cable grounds. In operation, the vessel often tows a grapple with several miles of cable out. In this type of work high slip ratios are encountered and these conditions favor cavitation of propeller blades.

In June 1938, seven of a new set of eight blades were hard surfaced with a Group III type alloy. This work was preceded by grinding of the new blade surfaces. A total of 35 sq. ft. was covered, using the atomic hydrogen method, at a cost of $822.50. A single layer technique was used, followed by light grinding to a smooth finish. In September 1938, these blades, together with a single unsurfaced blade, were put into service.

In December 1941, the set was removed and the pitting attack at the alloy-steel junction was repaired by depositing another layer of the same surfacing alloy further along the length of the blade and fusing into the original deposit. In this case, the oxyacetylene method was used. No cost figures are available, although it was stated to be more expensive than the first application. At the same time the blade which orginally had not been surfaced was now coated with so-called "lead wipe" (a tin-lead-antimony composition). In April 1944, the entire set of blades was again put into service on the same vessel.

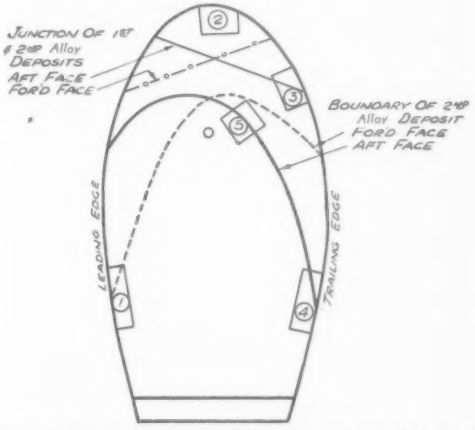


Fig. 1 Sketch showing location of samples and "alloy" coating

K. B. Young, H. J. Nichols and **M. J. Nolan** are Metallurgical Engineers, Physical Metallurgy Research Laboratories, Division of Mineral Dressing and Metallurgy, Bureau of Mines, Ottawa, Canada.

This paper is published by permission of the Director, Mines, Forests and Scientific Services Branch, Department of Mines and Resources, Ottawa, Canada.

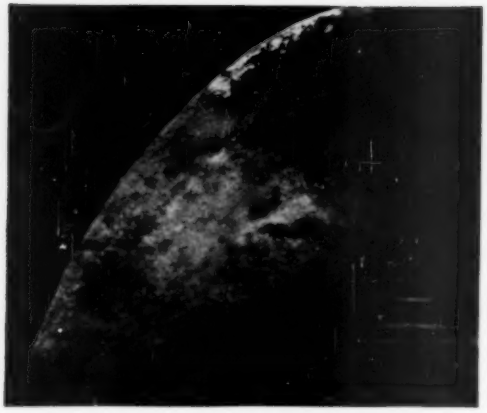


Fig. 2 Forward face, No. 4 starboard blade—alloy-coated
After 70 months of service. Representative of the general surface condition on the forward faces of alloy-coated blades

In November 1946, two blades were damaged and removed from service. One was an alloy-surfaced blade and the other the originally uncoated blade. In all, up to the time of this accident, their service life had been 55 mo. These two blades were replaced by two more, coated with lead wipe, and the service tests were resumed. In February 1948, the vessel was docked for a routine overhaul and at that time all blades were examined and photographed. In addition, the two damaged blades removed in November 1946 were subjected to a visual examination and the alloy-coated blade to metallurgical examination.

GENERAL EXAMINATION

(A) Alloy-Coated Blades

The junction line between the two deposits of the surfacing alloy was clearly visible. Figure 1 shows the location of the coatings and also the location of the samples removed from the coated blade which was damaged and removed in November 1946. These samples were used for the metallurgical examination reported below.

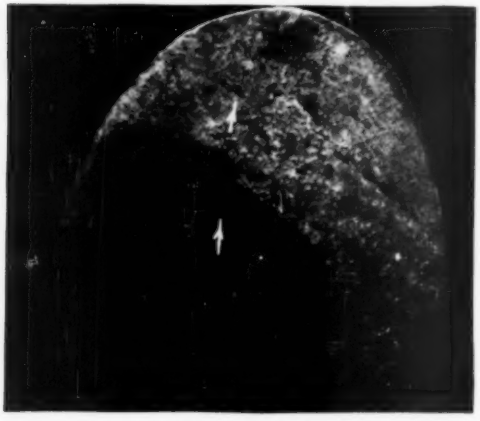


Fig. 3 After face, alloy-coated blade—damaged and removed, November, 1946
After 55 months of service. Representative of general surface condition of after faces of all alloy-coated blades. Arrows indicate junction between two alloy coatings and boundary attack in the steel

Fig. 4 After face, No. 4 starboard blade—alloy-coated
After 70 months of service. Note attack at junction of alloy coatings indicated by arrows

All blades revealed pitting of the uncoated steel adjacent to the boundary of the second alloy coating. The pitting had occurred in a band 3–4 in. wide with areas of advanced attack within this band. In the worst condition, the depth of pitting was $^{3}/_{16}$ to $^{3}/_{8}$ in. over a 1 in. wide area adjacent to the alloy but rapidly diminishing to $^{1}/_{8}$ in. over the remainder of the band. In general, the forward faces of the blades showed a more shallow attack. Figure 2 is representative of the general forward face of the blade, and Fig. 3 is typical of the condition of the after faces.

Several alloy-coated blades evidenced severe localized pitting in the alloy at the junction of the first and second coatings. Typical areas showing this attack are shown in Figs. 4 and 5. On the blades exhibiting this condition there was no evidence of a similar attack on the reverse face. It was noted that this form of attack was not

Fig. 5 After face, No. 4 port blade—alloy-coated
After 70 months of service. Arrows indicate junction cavity

Fig. 6 After face, original uncoated blade—damaged and removed, November 1946

Twenty-four months of service uncoated; 31 months of service coated with lead wipe

detectable on the alloy-coated blade damaged and removed in December 1946. It was stated that the blades which were not removed at that docking did not show at that time any sign of such attack. At the time of the examination being reported, four blades showed this condition on the after faces and two on the forward faces. Only one alloy-coated blade was entirely unaffected by this form of attack.

In general, the leading and trailing edges of all blades were in good condition. Where the "boundary" attack terminated at the edges at both faces, there was a reduction of $^1/_4$ to $^1/_2$ in. in the edge contour for a distance of 3 to 4 in. from the end of the coating. This effect was more pronounced on the trailing edge of the blade.

In addition to the advanced attack noted above, all of the alloy coatings revealed the following: (1) slight porosity at the junction line between the first and second alloy deposits; (2) fine, discontinuous hairline cracks; (3) slight undermining of the second alloy deposit at the boundary between it and the uncoated steel. The hairline cracks showed no preferred orientation and occurred in both alloy deposits on both faces and all edges.

Fig. 7 Forward face, original uncoated blade—damaged and removed, November 1946

Twenty-four months of service uncoated; 31 months of service coated with lead wipe

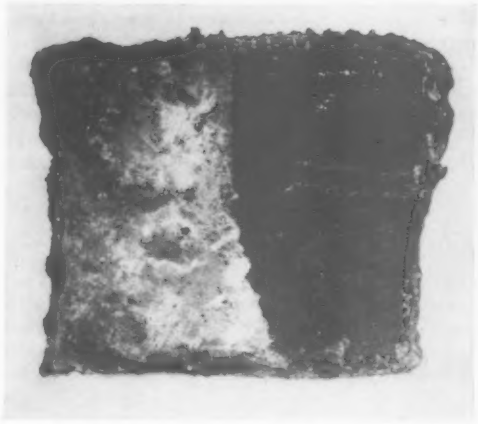


Fig. 8 Boundary between second alloy coating and uncoated steel, after face

Note pitted boundary attack. One-half actual size

With the exception of the above, the alloy coatings appeared to be relatively unaffected and are considered comparable to manganese bronze blades in similar service with regard to surface appearance. The uncoated areas of all blades exhibited uniform, shallow, general corrosion.

(B) Lead Wiped Blades

As described above, one blade was stated to have been 24 months in service uncoated, followed by 31 months in service after coating in England. When examined after this period of service, no trace of lead wipe could be found and severe pitting on both faces of the blade tip was noted. As shown in Figs. 6 and 7, the severity of attack was slightly greater on the after face. In addition the trailing edge for two-thirds of its length showed greater attack than the leading edge.

Two blades were examined after 15 months of service. These blades were coated with a lead wipe by an East

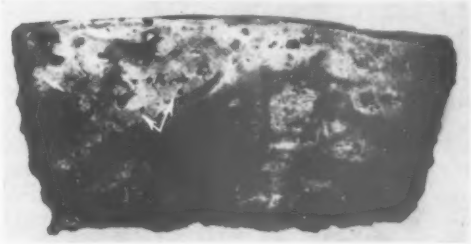


Fig. 9 Junction of first and second alloy coatings at trailing edge, after face

Note porosity and fine cracks indicated by arrows. One-third actual size

Coast concern. This lead wipe was of a different composition (Sn-Pb-Sb-Cu) than that previously referred to and these blades had seen service only with this coating. In this case the lead wipe coating was similar in area covered and thickness to that of the alloy-coated blades. A few isolated pits were visible on both faces. Both blades were in good condition and showed only the above-noted evidence of preferential attack.

METALLURGICAL EXAMINATION

The samples from the alloy-coated blade were subjected to a metallurgical examination. (The location of these samples is shown in Fig. 1.) Figures 8 and 9 show the surface conditions previously described. Chemical analysis of the cast-steel propeller base material, and spectrographic analysis of the two alloy coatings, yielded the data shown in Tables 1 and 2.

Table 1—Chemical Analysis, Cast-Steel Propeller Blade

Carbon, %	0.29
Phosphorus, %	0.032
Sulphur, %	0.040
Manganese, %	0.70
Silicon, %	0.30

Table 2—Spectrographic Analysis of Alloy Coatings

	First coating	*Second coating*
Major constituents	Co	Co
Minor constituents	Cr, W	Cr, W
Strong traces	Fe, Ni	Si, Fe, Al, Ni
Residuals	P, Mn, Si, V, Mo, Cu	P, Mn, V, Cu

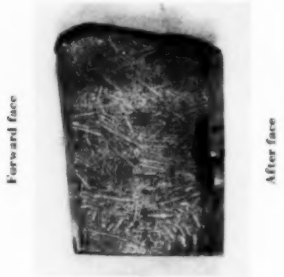


Fig. 10 Section near blade tip

Note various stages of galvanic attack at the roots of cracks in coatings. Actual size

Sections from samples 2, 3 and 5 were etched in 50% HCl for 30 min. at 180° F. Figures 10–12 show these sections after etching. Coating thicknesses were measured and found to fall within the ranges shown in Table 3.

Representative samples were cut, mounted, polished, etched and examined under the microscope. Figures 13–15 show, respectively, the junction line between the

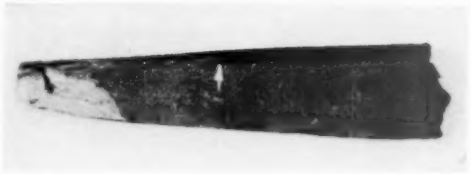


Fig. 11 Junction between the two coatings (arrow), trailing edge

After face at top. 60% actual size

Table 3

First coating, in.	0.05–0.11
Second coating, in.	0.12–0.17
Blade edges, in.	0.18–0.20

atomic hydrogen alloy deposit and the steel base, a similar area of the oxyacetylene deposit and typical intercrystalline cracks of the alloy deposits.

Hardness readings were obtained on cross-sectional samples of both coatings, using a Rockwell Hardness Tester and a 150-kg. load. The hardness figures obtained are shown in Table 4.

Table 4

First coating, Rockwell "C"	28–36
Second coating, Rockwell "C"	39–41

DISCUSSION

Microscopic examination, spectrographic analysis and hardness tests confirm the use of a Group III type hard-surfacing alloy. The differences in microstructure and hardnesses between the two deposits were noted. It is believed that these differences can be attributed to the different methods of deposition. The atomic hydrogen process, used in applying the first coating, is characterized by (1) a high maximum temperature at the outer edge of the arc fan, with, in this instance, fast cooling rates; (2) carbon burn-off. These characteristics would explain the finer eutectic and lower hardness of the atomic hydrogen deposit. These noted differences are not believed to be significant in this particular application and this view is supported by the uniform corrosion resistance of both deposits.

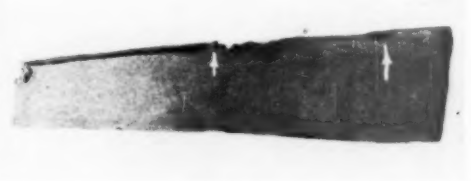


Fig. 12 Boundary of second alloy coating, center of blade

After face at top. Arrows indicate limits of galvanic corrosion. One-half actual size

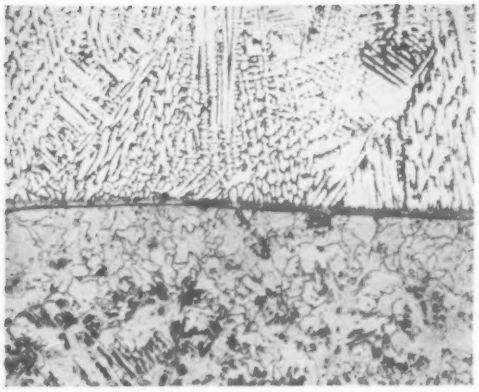


Fig. 13 Junction between atomic hydrogen alloy deposit and steel

Note intergranular crack in alloy at right and decarburized area in the steel. Murakami's etch. × 100

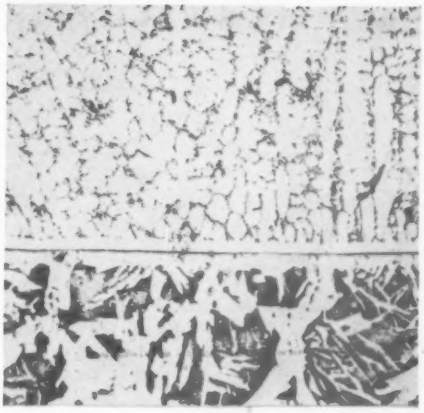


Fig. 14 Junction line between oxyacetylene deposit and steel

Compare with Fig. 13. Note relatively smaller area of decarburization in steel but evidence of greater heat input in base material. Murakami's etch. × 100

Since no sacrificial zinc or aluminum plates were used during the test period, galvanic corrosion is considered to be the basic cause of the attacks noted. Cavitation is possible also, in view of the service conditions, as a contributing factor aggravating the condition at the alloy boundary on the after faces of the blades. The fine cracks in the alloy coatings, which have permitted subsurface galvanic corrosion, are characteristic of the coatings produced by some Group III alloys where insufficient preheat has been used before deposition. In many industrial applications checking of this type is immaterial but in this case it could be serious. The notches so produced may spread in service under the conditions of pulsating stresses and lead to complete failure or spalling-off of the alloy coating.

Corrosion at the junction line between the two alloy coatings was noted. The porosity and cracking encountered when some Group III type alloy deposits are re-melted is difficult to avoid, even by skilled operators. Detection of such defects at the junction line is, therefore, not surprising. The corrosion at this area is believed to be due to penetration of salt water through these defects to the steel base with consequent galvanic corrosion. For this reason, single applications of alloys are advisable. In the absence of such junction line attack, the service life of coated blades would be determined by the degree of galvanic corrosion occurring at the alloy-steel boundary. Due to the relative positions of such surfacing alloys and steel in the galvanic series, this type of corrosion will occur regardless of the distance the alloy is extended down the blade. This assumes the absence of sacrificial zinc or aluminum plates which ordinarily retard such corrosion. The results obtainable with alloy-coated blades in combination with sacrificial plates at the termination of the coating make for interesting speculation, but no data for such a service test are currently available.

The coating of the cast-steel blades with Group III type alloy has apparently extended the service life of the blades over that of uncoated blades. While the alloy-coated blades are still in service, their life expectancy at the time of the visual examination (February 1948) is not considered to be great.

The condition of the two blades coated with lead wipe is, after 15 months of service, sufficiently good to arouse considerable interest in what their condition would be after service life equal to those of the alloy-coated blades. Until such an examination is completed it is idle to speculate on the relative merits of the two coatings.

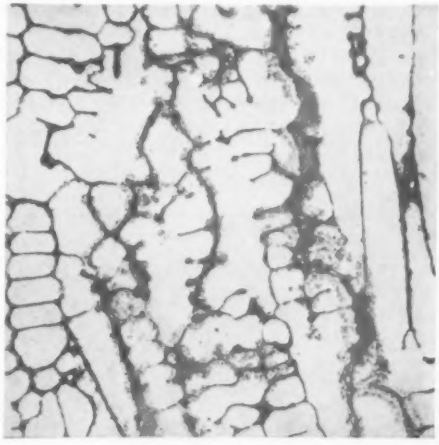
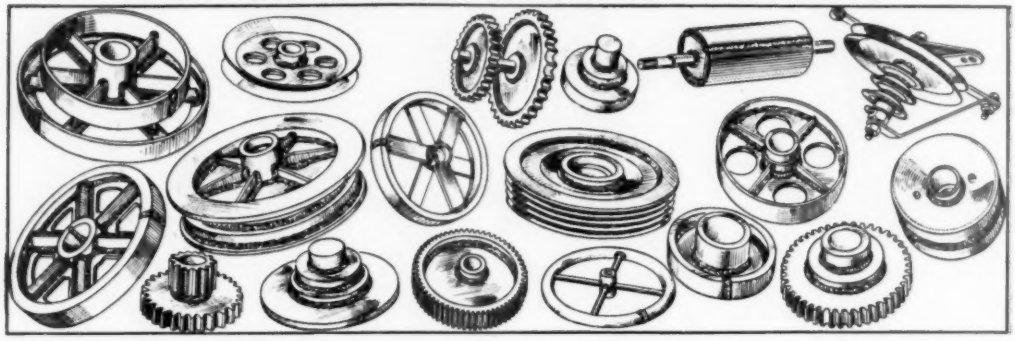


Fig. 15 Intercrystalline cracks filled with corrosion products in first alloy deposit

Murakami's etch. × 500

PRACTICAL WELDER AND DESIGNER

Examples of different wheels now being weld-built at lower cost for all types of machinery



How to Design Wheels

Thought starters on welded design

STEEL is generally three times stronger and two and a half times stiffer than gray iron. As a result, machinery component parts made with welded steel construction can have thinner wall sections and thus less material weight. Welded design permits different steels to be used on any part which, when heat treated, provide all necessary strength, hardness and bearing qualities. In many cases, component parts for a weldment can be rough machined before welding, leaving only light finishing cuts to be taken later.

Typical of stronger, lighter machinery construction possible at low cost with welded steel design is the fabrication of wheels. Built in several different ways depending upon the quantity to be made and the type of shop equipment available for fabrication, wheels are basically designed around three elements—the hub, web and rim.

The Hub is often made by fillet welding one or more bosses to the web as shown in Fig. 2. Normally made from bar stock, the bosses are prechamfered, allowing deeper weld penetration and greater strength. On larger sizes, these bosses can be flame cut from steel plate. Another construction often used is an integral hub turned from bar stock or tubing as a simple lathe

This article is published through the courtesy of the Lincoln Electric Co., Cleveland, Ohio.

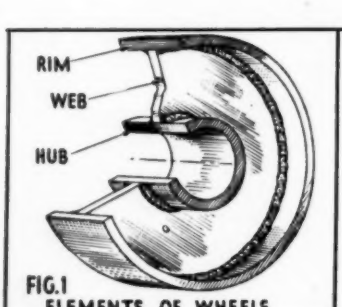


FIG. 1 ELEMENTS OF WHEELS

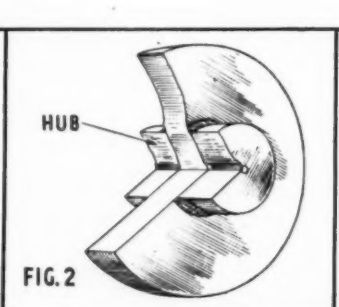


FIG. 2

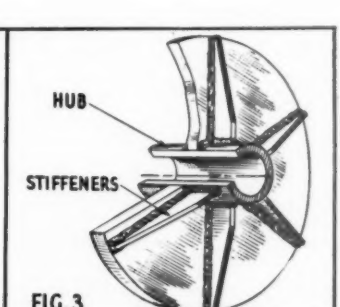
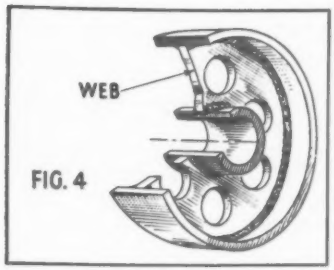
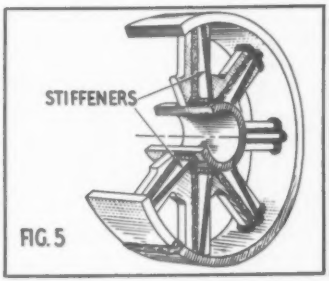
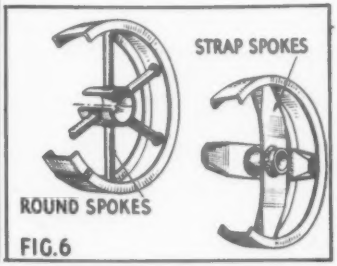


FIG. 3







operation (Fig. 3) and fillet welded to the web. To resist heavy side thrust, stiffeners cut from steel plate are fillet welded to hub and web.

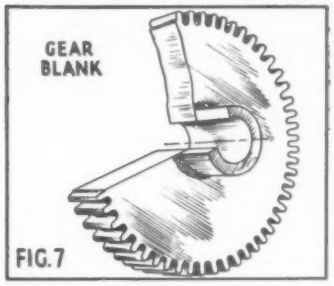
The Web. Several designs are considered, depending on the load to be carried and the restrictions in weight. Simplest construction is a solid disk cut or blanked from plate. To reduce weight, holes are cut out of the web (Fig. 4). Similarly, triangular shapes can be flame cut from the disk with resulting shape simulating spoke-type construction (Fig. 5). Additional side bracing is secured with stiffeners. Stiffeners permit thinner web sections, desirable where minimum weight is an essential item.

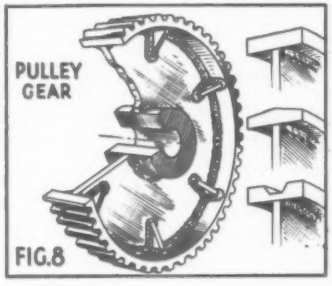
Plain spokes made from bar stock, tubing or triangular shapes are commonly used in wheel construction (Fig. 6). The spokes are scarfed to conform with the contour of the hub and rim and then fillet welded. Tapering the spokes to be thicker at the hub and thinner at the rim increases the unit strength and enhances the product appearance.

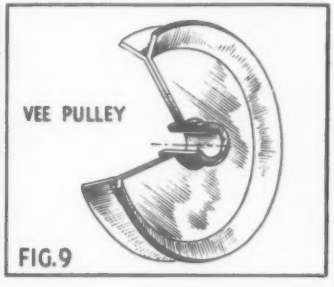
Rugged in design is the simple spoke-type construction shown also in Fig. 6. Two plain straps are brake-formed and welded to the rim. If added hub bearing is needed, a boss is welded to both straps.

The Rim. In many cases the web is thick enough that its outer diameter can serve also as the wheel rim. An example of this is the conventional gear blank or sprocket shown in Fig. 7, having gear teeth cut on the outside diameter.

To secure greater rim width, a rolled steel bar is fillet welded to the web (Fig. 8). The ends of the rim are butt welded with mild steel electrode resulting in a joint having free machining qualities equal to those of the parent metal. Stiffeners welded to the rim and web strengthen the weldment for heavy loading especially where wide rims are involved. Gear teeth are cut in the rim, or the rim contour is machined for flat or V-belt drive.

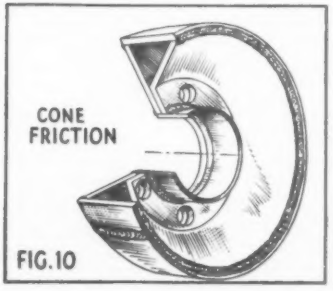


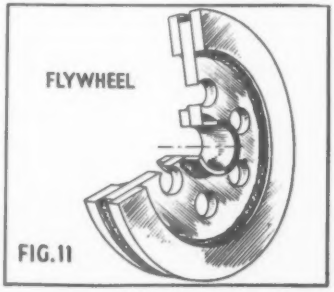


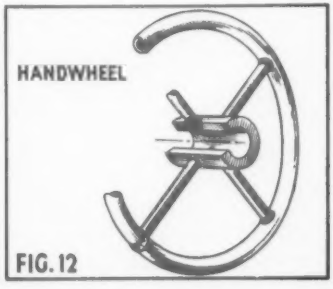


Alternate construction for building vee pulleys incorporates two formed disks butt welded together as shown in Fig. 9. This design is used where larger quantities are made and dies are available for forming the web sections.

Cone Friction Wheel. A web, formed with a taper







face, as shown in Fig. 10, is fillet welded to the hub. For added rigidity, the taper-faced web member is backed with a flat disk and a rolled rim welded to the outside diameter. After welding, the complete assembly can be machined with light finishing cuts to obtain size and concentricity.

Flywheels. Arc-welded construction of flywheels permits metal to be concentrated where it is needed most . . . at the rim . . . resulting in a higher inertia-to-weight factor than with other types of construction. Rims formed from steel bars or cut from plate are welded to the web as illustrated in Fig. 11. The web diameter is made slightly smaller than the outside diameter of the rim to allow deeper weld penetration.

Hand Wheels. Hand wheels consist of a plain round rim formed from round bar stock or tubing. Welded-steel hand wheels are superior to other types in that they will not fracture.

For fast welding, component parts are located and held in simple, clamp-type fixtures. On larger quantities, the fixtures may be tilted and rotated by power for fast downhand manual welding or with the "Automatic Lincolnweld."

Utility Problems in Supplying Power For Resistance Welding

by H. B. Wood

FOR the past 15 years or so, the application of resistance welding has progressed greatly, increasing correspondingly the number of welder services on the utility system. With the increased use of this type of welding during the war, further demand for welder services will undoubtedly accelerate during the coming years. Many schemes are used to connect welder loads to provide adequate voltage without undue annoyance to other customers. When adequate data are available concerning the welder and utility system, service can usually be provided at no great cost to satisfy the above conditions.

Three major problems confront the utility engineer in serving welding loads. They are flicker to other customers served from the same distribution system, adequate voltage at the welder terminals and low revenue at high investment cost. Certain limitations on the amount of fluctuation at various frequencies have been established beyond which flicker to lights would be objectionable, the most critical frequency being around six fluctuations per second. The amount of noticeable or objectionable voltage drop may be reduced and voltage at the welder may be improved by various schemes for reducing the system impedance as viewed at the customer's installation. The repayment of investment cost to the utility for special installations to serve welders is afforded in a surcharge.

It should be emphasized that the limitations in the amount of fluctuation and frequency of fluctuation, or addition of a surcharge are not fashioned as penalties for connecting welders to the utility system, but these limitations and surcharges are established practice applying to any form of fluctuating load.

The system impedance to the secondary of the distribution transformer on the Duquesne Light Co. 4-kv. system may vary between approximately 1.5 and 17 ohms. For other voltages higher than 4 kv., the system impedance overlaps somewhat but decreases to lower values than those for the 4-kv. system. Since the voltage drop caused by a specific welder load is its load current multiplied by the system impedance, it is quite possible that, depending on the location on the system, the welder load may be too great to keep voltage flickers and terminal voltage within established limits.

For those cases where flicker is too great or voltage inadequate, many schemes may be used to bring these conditions within limits, such as to replace a 2300/230 volt transformer with 4000/230 volt transformer with corresponding reconnection, connect welder to a 3ϕ star-delta bank, replace primary circuit conductors, install a separate feed, install series capacitors in the primary feed, install a translator or other similar plans.

Most of the utility operating problems involved in the operation of the welder may be solved in advance of trouble provided adequate welder data and system impedance data are available. For this reason, the Duquesne Light Co. requests the customer to fill in a "Welder Data Sheet" when requesting service. He supplies the utility with all pertinent nameplate data, including maximum currents that the welder can draw even though this may not be needed in the proposed demand of the welder, number of welds per minute and expected voltage and current at the proposed operating cycle. Other variations in data are also requested on the sheet depending upon the type of welder it is proposed to serve. Using these data and system impedance data, the utility engineer is able to make calculations using various types of connections and thus determine the cheapest method of connection which will provide adequate voltage and minimize flicker to other customers.

All of the above discussion of the utility problems points out several major facts. Cooperation between the manufacturer of resistance welders, the user of the welders and the utility is of utmost importance in providing an adequate power supply for resistance welders. The customer should consult with his utility before purchasing a welder so that no welder of such size or in such location will require a service of prohibitive cost.

H. B. Wood is connected with the Duquesne Light Co., Pittsburgh, Pa.

This paper was presented at the Conference on Electric Welding sponsored by the A.I.E.E. in cooperation with Detroit Sections, A.W.S., A.I.E.E. and Industrial Electrical Eng. Soc. of Detroit, held in Detroit on Dec. 6–8, 1948.

Copper and Its Alloys

COPPER and its alloys find numerous uses because of their high electrical and thermal conductivities and their corrosion resistance toward water and other liquids, as well as toward many industrial atmospheres. Many alloys of copper have special characteristics which make them useful for bearings and other machine elements.

Several types of copper metal are available, the properties and behavior of the metal being strongly influenced by its oxygen content. Tough pitch copper, containing about 0.03 to 0.06% oxygen, is made by stirring impure molten copper (containing appreciable copper oxide) with wooden poles to reduce the oxygen content. To meet certain requirements there are grades of copper with lower oxygen content, commercially termed "deoxidized copper" and "oxygen-free copper." Deoxidized copper is manufactured by treating it in the molten state with a strong deoxidizer such as phosphorus, silicon, calcium or lithium. Oxygen-free copper is made by melting commercially pure copper under conditions that prevent the absorption of oxygen. In one method the metal is allowed to flow through charcoal to produce OFHC, the oxygen-free high conductivity grade. The presence of even small quantities of oxygen reduces ductility and weldability. Moreover, when oxygen-containing copper is heated in a reducing atmosphere above 700° F.,† chemical reaction takes place between the reducing gases and oxides of copper at grain boundaries, so that cracks and brittleness result.

Pure copper is relatively soft, with tensile and yield strengths of about 32,000 and 10,000 psi., respectively. These are increased considerably by even a small amount of cold work, but temperatures as low as 400° F. will begin to soften the cold-worked material.

Other metals (commonly zinc, tin, silicon, aluminum, nickel, lead and beryllium) are added to copper as alloying elements for a number of reasons, among them: to increase strength and corrosion resistance; to obtain sounder castings; to reduce metal cost by alloying with a cheaper metal; and to improve machinability and elastic properties. A large variety of alloys with a wide range of properties in cast and wrought forms is available. Specific compositions and properties will be found in manufacturers' literature and in metal handbooks.

Copper and its alloys are easily hot or cold worked. In general the range of working for the former is from about 1100 to 1650° F.

Heat treatment of pure copper is carried out at 1100° F. at which temperature softening takes place without excessive grain growth; this treatment is carried out only to relieve cold-working effects.

The joining of copper and its alloys by fusion welding to produce fully sound, strong structures is a comparatively recent development. Welding may be carried out by gas, coated electrode fusion welding, carbon arc or resistance methods. Brazing techniques may also be used. The gas methods may employ oxyacetylene, atomic hydrogen or heliarc.

The extremely high thermal conductivity of copper (approximately five times that of ordinary steels) requires preheating of base metal to prevent cracking due to rapid cooling. In carbon arc welding, preheat temperatures as low as 400° F. have been used. However, higher temperatures, up to 1200° F. may be required, depending on the size, shape and design of the structure and the welding technique employed. Higher temperatures allow better control of metal fluidity and are preferred wherever practicable.

References

Garriott, F. E., "Arc Welding of Copper and Copper Base Alloys," THE WELDING JOURNAL, **26** (10), 907-915 (1947).

Vreeland, J. J., "Arc Welding Copper Vessels," *ibid.*, **27** (2) 125-129 (1948).

1942 Welding Handbook, AMERICAN WELDING SOCIETY, Chapter 22.

R. A. Wilkins and E. S. Bunn, "Copper and Its Alloys," McGraw-Hill Publishing Co.

This article appeared in *Tempil Topics*, Vol. 4, No. 1.

† Tempilstiks® are a convenient way of checking temperatures. Sample Tempil® Pellets are available on request.

COMPARED METALS	Approx. melt. pt. in °F.	Weight in lbs. per cu. in.	Weight in lbs. per cu. ft.	Weight ratio **	Specific heat ratio **	Latent heat ratio **	Thermal conduct ratio **	Expansion ratio **	Modulus in millions
COPPER*	1980	.323	560	1.0	1.0	1.0	1.0	1.0	16
ALUMINUM*	1215	.098	170	0.30	2.5	1.3	0.55	1.5	10
MAGNESIUM*	1204	.063	109	0.20	2.8	0.73	0.40	1.6	6.3
STEEL	2700	.284	490	0.88	1.2	0.94	0.20	0.7	30
18-8 STAINLESS	2600	.286	495	0.89	1.3	0.94	0.07	1.0	30
NICKEL*	2650	.322	560	1.0	1.2	1.03	0.15	0.84	30
BERYLLIUM*	2345	.066	114	0.21	4.7	5.0	0.42	0.72	43

* Commercially pure metal. ** Approximate ratios—Pure Copper = 1.

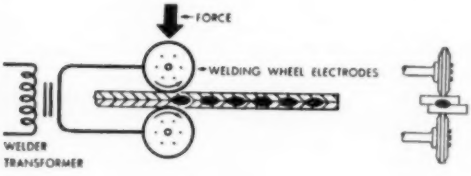
Designing for Welding—Part II

In the previous installment, basic principles and general types of spot, projection and seam welding were discussed

By Wallace A. Stanley

MECHANICALLY, roll spot welding is actually another form of seam welding. It is used where water or gas tight seams are not required. In roll spot welding the spots do not overlap. Spacing between spots can be varied by adjustment of the timing mechanism. The strength of the joint produced is roughly the same as if the joint had been produced by a row of individual spot welds. The continuous rolling process is quite fast of course—much faster than individual spot welding. Roll spot welding may be performed in stationary seam welders with the work fed through the machine. Or, the work may be clamped to a fixture—using traveling seam welder wheels. Or, portable seam welding equipment may be used. Selection of equipment depends largely on the nature of the product and best method of handling of the material.

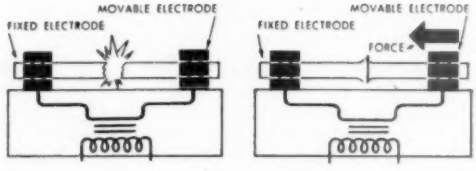
ROLL SPOT WELDING



Where it is desired to join pieces endwise, butt welding is employed. This may be in the form of either upset or flash welding. In upset welding, the pieces are brought together under pressure, each being held in an electrode. Current is applied and the heat created at the joint acts as in spot welding to fuse the parts together. Continued pressure forms an upset weld nugget. As in spot welding, the pieces are held in place until temperature has dropped below the plastic point.

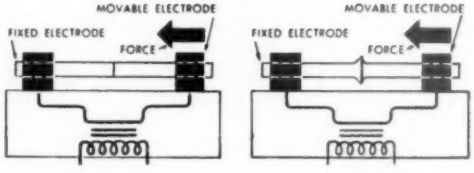
Wallace A. Stanley is Application Engineer at the Progressive Welder Co.

FLASH BUTT WELDING



Flash butt welding is quite similar to upset welding, except that the heat to melt the joint is caused by arcing rather than conduction. Burning of metallic gases between the pieces assist in rapidly raising the temperature. The pieces are brought together slowly as metal is burned away. When the ends are thoroughly hot, the pieces are forced together rapidly and the current is cut off. The metal in plastic form together with any impurities at the surface are forced out into an "upset" weld nugget, only clean metal being left in the weld. Again, the work is allowed to cool before removing.

UPSET BUTT WELD

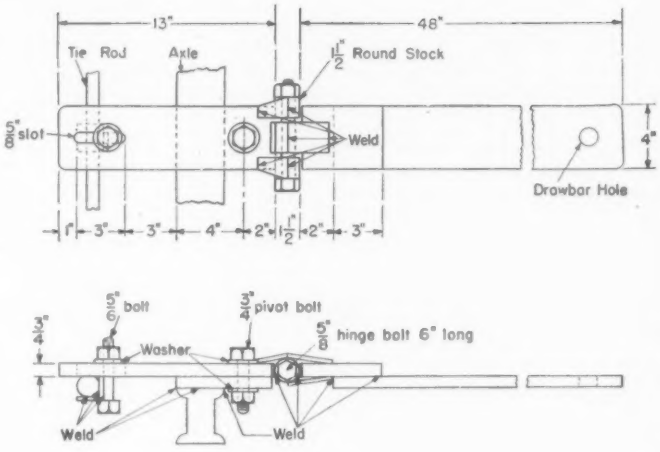


Butt welding may be applied to all manner of problems. For instance, a high speed steel tool bit may be welded to a mild steel shank, obtaining thereby the best characteristics for each end of a tool. A tubular part may be welded to a solid round. Small pieces can be welded to large ones. Two pieces of entirely dissimilar metals may be welded together. As a matter of fact any material weldable by any process can be butt welded.

(*Continued in next issue*)

Handy Welded Steering Hitch Easy to Make

USING a small General Electric welder and pieces of scrap metal in his spare time at home, a G-E employee built a handy steering hitch, diagrammed here, for one of his neighbors. Eliminating the need for a bolster, this simple hitch was designed for use with an old Buick jalopy which had been converted into a farm wagon. By changing some of the dimensions shown, it can readily be adapted for use with trailers made from other makes of cars. Where heavy loads are to be hauled, a piece of channel steel would be more practical for the tongue than the $^3/_4$- x 4-in. bar used here.



Economical Service for Resistance Welders

by E. F. Dissmeyer

THE survival of our economic system is dependent upon an increasingly higher standard of living which requires continual improvement in production methods. Most new production methods are becoming increasingly dependent upon the use of electric power. Resistance type welding is one of the more important methods being used in the accelerated and economical production of goods. The cost of serving such loads is predominately that of investment in utility plant. The equitable investment of available capital in electricity supply systems to serve welding equipment along with other types of loads therefore requires the proper application of welders and the coordination of their load characteristics with others served by the power supply system. The maximum of benefits can be obtained only by the cooperative effort of the welder user and the utility supplying the electric service.

Where the resistance welding load is small compared to other motor and lighting loads, the user may be able to apply and install resistance welding equipment without seriously affecting the investment required by the power supply company. It is generally agreed, however, that in some cases the revenue received under usual power rates from resistance welders alone will not justify the expenditures required to isolate them properly from other loads so that they can be supplied without disturbing the service of other customers. Decentralization of industry, together with the installation of fluctuating loads in remote areas, presents a particularly troublesome problem.

As a general rule the user should contact the power supply company prior to the purchase of resistance welding equipment. Certain pertinent data regarding the proposed welder installation will be required by the utility engineers who then will be able to inform the user regarding power supply availability and limitations. Also in the case of smaller users the power sales engineers may be of considerable help in not only the application of the welding equipment but also in the selection of a suitable distribution system for the plant.

The utility should be provided with a complete description of the proposed welder including the type of machine, its kva. rating, primary voltage and maximum open-circuit secondary voltage ratings together with the available taps. The maximum secondary current and power factor are also needed so that the effect of the maximum welder load on the service of other customers can be determined. In many cases a welder may require different inputs for various portions of a welding operation or it may be used for more than one type of weld. In such cases a description of each

E. F. Dissmeyer is connected with The Commonwealth and Southern Corp., Jackson, Mich. This paper was presented at the Conference on Electric Welding sponsored by the A.I.E.E., in cooperation with Detroit Sections, A.W.S., A.I.E.E. and the Industrial Electrical Engineering Society of Detroit, held in Detroit on Dec. 6-8, 1948.

welding operation should be provided, including the kva. and kw. inputs of the welder at rated voltage. Information relative to the length of time of the weld together with a description of the type of switching equipment to be used is essential if the utility engineer is to determine the facilities required to supply the load.

In applying the welder the user should select a machine having the smallest kva. input compatible with the required speed of production and quality of weld. In general, properly applied welding equipment results in a minimum investment in machines and in the user's plant distribution system.

Customers should not overlook the possibility of using stored energy and three-phase-type welders. In many cases one of this type of welder or the use of series capacitors will provide an economical solution for installations where voltage fluctuations would be excessive if the conventional single-phase-type machine were installed. Voltage fluctuations within the customer's own plant may be just as important as those which disturb the service of other customers.

The principles outlined herewith have been successfully applied by many users and utilities resulting in satisfactory and economical installations.

Spirit Level Positions Carriage for Welding Girth Seams

A SMALL spirit level fastened to the carriage of the Unionmelt welding machine provides an easy method for checking the position of the welding rod when making girth seams. Accurate positioning of the welding rod is necessary to obtain proper welding conditions since the fluid weld puddle must be kept close to the horizontal position. For this reason, on inside girth seams, the rod is set ahead of the low point so that the puddle will form at the bottom of the curvature and start to solidify while the surface is horizontal.

Welding takes place electrically beneath a cover of granular welding composition, without glare, flash or spatter. In the welding zone, the granular composition fuses and submerges the weld puddle. On cooling, the fused composition solidifies and detaches itself, leaving the clean, uniform weld surface shown here.

The operator looks at level (*A*) and adjusts the speed of the carriage so that the bubble remains centered. Thus, the speed of the carriage is matched with the rotation of the tank and the welding rod is kept at the proper lead distance. Another feature of this installation is a rack and pinion (*B*) placed on the carriage under the mounting head. This makes it possible to quickly and easily position the welding head over the seam.

FLOW AND FRACTURE OF METALS

The scientific phenomena involved in the flow and fracture of metals has engaged the attention of some of the ablest scientists in the world in recent years. The problem is particularly important in welded structures where the monolithic character of a welded assembly brings into play stresses of a three-dimensional character. Stress concentrations, temperature, quality of steel, rates of loading, degree of constraint, are only a few of the many complex variables involved in the thorough understanding of the subject. In order to make available to engineers and research workers the best existing information, two comprehensive reviews were prepared on the subject. One of them was made by Major Holloman under the supervision of the Welding Research Council and the other by Dr. Gensamer and his associates for the U. S. Navy. Each of these are already available in book form at $1.00 per copy. Orders may be placed for either or both of these books at once. Address orders to:

AMERICAN WELDING SOCIETY

33 West 39th Street, New York 18, N. Y.

the AMERICAN WELDING SOCIETY

activities • related events

BOUND VOLUMES OF THE WELDING JOURNAL

Bound volumes of THE WELDING JOURNAL for the years 1930, 1931, 1932, 1933, 1934, 1935, 1937 and 1938 may be purchased at a special price of $5.00 per bound volume or $30 for the complete eight (8) years as listed. The Journals are bound in attractive imitation black leather covers. *Act now as this offer expires April 1, 1949.* Orders may be placed with the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

A Subject and Authors Index for any or all of these years will be sent upon request.

1948–49 Nominating Committee American Welding Society

With the approval of the Board of Directors, the President has appointed the following members to constitute the 1948–49 Nominating Committee: H. O. Hill, Chairman, Bethlehem Steel Co., Bethlehem, Pa.; F. W. Davis, E. B. Badger & Sons Co., 75 Pitts St., Boston, Mass.; R. H. Macy, The Ingalls Shipbuilding Corp., Pascagoula, Miss.; H. M. Priest, U. S. Steel Corp. Subs., Frick Bldg., Pittsburgh, Pa.; C. M. Underwood, Northern Ordnance Co., Minneapolis, Minn.; J. H. Weigel, Combustion Engineering Co., Inc., St. Louis, Mo.; V. J. Whitlock, Eagle Metals Co., 3628 E. Marginal Way, Seattle 4, Wash.

The By-Laws require that these names be published in the JOURNAL on or before March 1st. The Committee is required to deliver to the Secretary in writing, on or before the 10th day of May, the names of its nominees for the various elected offices next falling vacant, together with the written acceptance of each nominee.

The purpose of publishing the names of the Nominating Committee in the JOURNAL is to provide every member with an opportunity to make suggestions to the Nominating Committee. To be effective, it is essential that these suggestions be sent in at once as, naturally, the Nominating Committee will be required to hold early meetings in order to fulfill its duties as required by the By-Laws.

The offices to be filled are: President, First Vice-President, Second Vice-President (all for a term of one year), and four Directors-at-Large (all for a term of three years). Present incumbents of the offices of President, First Vice-President and Second Vice-President are eligible for another term. The incumbents for Directors-at-Large are not eligible for re-election, according to the By-Laws, Article VIII, Section 6. The Directors-at-Large are selected by the Nominating Committee with due consideration to geographical distribution.

Present officers whose terms expire next October are: President, G. N. Sieger; First Vice-President, O. B. J. Fraser; Second Vice-President, H. W. Pierce; Directors: D. H. Corey, J. F. Maine, E. L. Mathy and L. S. McPhee.

Board of Directors Meeting

A meeting of the Board of Directors of the AMERICAN WELDING SOCIETY was held in the Hotel New Yorker, New York City, on Thursday, Dec. 2, 1948, with the following in attendance:

Members: D. Arnott, J. J. Chyle, G. E. Claussen, D. H. Corey, R. S. Donald, O. B. J. Fraser, W. F. Hess, H. O. Hill, J. H. Humberstone, T. M. Jackson, T. B. Jefferson, C. I. MacGuffie, H. W. Pierce, J. F. Maine, G. N. Sieger and J. B. Tinnon.

By Invitation: E. V. David, Chairman, Convention Committee and A. C. Weigel, Chairman, Special Committee on A.W.S.-A.S.M. Negotiations.

Staff Officers: J. G. Magrath, *Executive Secretary;* M. M. Kelly, *Secretary;* W. Spraragen, *Editor,* THE WELDING JOURNAL S. A. Greenberg, *Technical Secretary;* F. J. Mooney, *Manager,* Service Department.

Finances

Annual Report—1947–48. In presenting report on financial operations of the SOCIETY for the fiscal year ended Sept. 30, 1948, the Chairman of the Finance Committee called special attention to the following points: Although the total income for this year bettered that of the previous year by $5400, it fell short of the year's budgeted income by $40,700. The large differential between the budgeted and actual experience was caused, for the most part, by variance in (*a*) income from membership dues in the amount of $32,800, because of the postponement of proposed membership drive; (*b*) JOURNAL advertising, caused by raising the amount budgeted over the previous year's actuality to cover cost of expanded activity program; actually this year's JOURNAL income approximated the previous year's; (*c*) income anticipated from sale of *Welding Metallurgy* and the *Handbook* did not materialize since proposed new issues were not published.

While the total expenses for the year showed a saving of approximately $21,000 over the budgeted figure, this year's expense was increased over the previous year by $30,365.

Thus, the operations for the year resulted in an excess of expense over income in the amount of $19,400 as compared with an excess of income over expense for the previous year in the amount of $5000.

1948–49 Annual Budget

Consideration was given to proposed budget for the new fiscal year, commencing Oct. 1, 1948, and the accompanying communication of the auditor, dated Nov. 23, 1948, and of the Chairman of the Finance Committee, dated Nov. 26, 1948, relating thereto. In presenting this budget, the Finance Committee stressed the importance of periodical scrutiny of the actual experience with the budgeted income and expense, throughout the fiscal year, to insure against any loss beyond that budgeted. A quarterly review was recommended.

In response to questions raised regarding method of apportioning overhead expense against the various departments, the auditor explained that the method of charging the various functions with overhead on the basis of the value of the estimated personnel time requirements to conduct the affairs of the various departments is one that was established arbitrarily over ten years ago by the Finance Committee, and approved by the Board of Directors, then in office. No better method of estimating operational costs has been proposed since that time. At the beginning of every fiscal year, Headquarters' (overhead) expense is given separately in the budget and the apportionment of the overhead against each department is shown in the budget. Thereafter, in the quarterly reports furnished to the Board, the figure shown against each function includes direct and overhead charges. In order to enable the Board to determine more readily the direct charges against the functional items, such as THE WELDING JOURNAL, *Welding Handbook,* Educational Books, Annual Meeting, Membership, Section

and Educational Activities, it was deemed advisable in future to show the overhead separate from the direct charges. On request, Mr. Joseph, Auditor, agreed in future to submit financial statements as presently submitted, and also in the form wherein the overhead expenses will be shown separately from the direct expenses.

In respect to membership revenue possibility for the current year, the Executive Secretary sounded a warning note regarding membership delinquency and losses this year, compared with a year ago, which, he stated, he believed is very definitely tied into the increase in dues. To stem the tide in membership losses, he sought the guidance and active assistance of the Board of Directors, particularly the District Vice-Presidents and Directors located in Sections. It is his plan to concentrate this year on getting new members and retaining the interest of present members. It was the sense of the meeting that the revamping of the JOURNAL to meet the wishes of the membership as expressed to the Executive Secretary, and the increased services to the membership, Sections and welding industry, to meet their demands, should be productive of greater interest and willingness on the part of the membership and welding industry to support the SOCIETY.

Welding Research Council Subscription

Upon due consideration, request for renewal of A.W.S. annual subscription of $250 to the work of the Welding Research Council, was approved.

Standing Committee Appointments

List of recommended personnel of Standing Committees for the fiscal year 1948–49 was distributed at the meeting. With the addition of the name of a representative from the A. O. Smith Corp. (to be furnished by Mr. Chyle) to the members of the Manufacturers Committee personnel list of A.W.S. Standing Committees for the year 1948–49, was approved.

Permanent Speaker and Lecture Bureau

Recommendation of Executive Secretary for the institution of subject bureau as a means of improving Section meetings, was considered.

After deliberation, it was voted to authorize the President to appoint a permanent Speaker and Lecture Bureau, with scope and personnel as outlined in communication of Executive Secretary, dated Nov. 16, 1948. It was suggested, if space permits, that a screened list of speakers for Section meetings, to be furnished by the Executive Secretary, be published periodically in THE WELDING JOURNAL for the benefit of Section Officers.

District Boundary Lines

The Board cogitated on matter of By-Law change in order to avoid burdening the Board with responsibility of determining or adjusting District boundaries, as recommended in communication of Executive Secretary, dated Nov. 16, 1948. It was the sense of the meeting that word "determine" in Article VI, Section 1, "Geographical Districts," of the By-Laws, can be interpreted to mean "approve" and therefore no change in the By-Laws is needed. It was the opinion that responsibility for determining or adjusting District boundaries rests with the Executive Secretary, in consultation with the District Executive Committees and Section Advisory Committee and their findings, with recommendations, should be offered to the Directors for approval.

Technical Activities Committee Recommendations

Recommendations submitted in communication of Technical Secretary, dated Nov. 15, 1948, were duly considered and approved. It was the sense of the meeting that inasmuch as the Board of Directors is not expected to pass upon the technical content of a standard, but merely to accept or decline to accept the proposed standard for publication as an A.W.S. standard, or tentative standard, it is not necessary in future for T.A.C. to furnish the Board of Directors with copy of proposed standard referred to in its recommendation. The Secretary was directed to so advise T.A.C.

International Institute of Welding

Review was made of report of Executive Secretary of meeting of National Officers of A.W.S. interested directly in the International Institute of Welding, held on Dec. 1, 1948, for purpose of discussing and seeking clarification of situations that had arisen in connection with the

INDEX TO ADVERTISERS

Air Reduction Sales Co.	Outside back cover
Alloy Rods Co.	191
Aluminum Company of America	175
American Brass Company	Inside back cover
American Chain & Cable	181
Ampco Metal, Inc.	185
Anti-Borax Compound Company, Inc.	176
Arcos Corporation	193
Bastian-Blessing Co.	174
The Burdett Oxygen Co	183
The Champion Rivet Company	169
Cullen-Friestedt Co.	196
Dockson Corporation	178
Eastman Kodak Company	177
Eisler Engineering Co., Inc.	192
Electroloy Co., Inc.	186
Eutectic Welding Alloys Corp.	178
General Electric Co.	179, 200 & 201
Harnischfeger Corporation	208
Hobart Brothers Company	105
The International Nickel Co., Inc.	188 & 189
The Lincoln Electric Company	171
The Linde Air Products Company	109
Lukens Steel Company	167 & 187
P. R. Mallory & Co., Inc.	106
Metal & Thermit Corporation	107
National Carbide Corporation	172
New Mexico Steel Co.	192
Oakite Products Inc.	176
Page Steel & Wire Division	181
Penn Tool & Machine Co.	173
The Reid-Avery Co., Inc.	203
Revere Copper & Brass Incorporated	195
Shawinigan Products Corporation	194
Tempil° Corporation	168
Tweco Products Company	Inside front cover
Union Carbide and Carbon Corp.	109
Victor Equipment Company	110
J. H. Williams & Co.	176

CLAD FABRICATION DATA
STEP No. 1: WELDING THE STEEL SIDE
STEP No. 2: WELDING THE CLAD SIDE
LUKENS CLAD STEELS
The Widest Range of Clad Materials Available to Industry
LUKENS STEEL COMPANY
COATESVILLE, PENNSYLVANIA
To hang in your shop

Lukens will send you this instruction card on welding clad steels—Nickel-Clad, Stainless-Clad, Inconel-Clad and Monel-Clad. It gives data on preparation of the plate, electrodes and number of passes to use, current densities, and so on.

For this wall chart or for the 100-page book, "Fabrication of Lukens Clad Steels", write Lukens Steel Company, 407 Lukens Building, Coatesville, Pa.

LUKENS
Nickel-Clad Stainless-Clad
Inconel-Clad Monel-Clad
STEELS

Two 16mm Kodachrome motion pictures—"The Manufacture of Lukens Clad Steels" (silent) and "Solving Corrosion Problems" (with sound)—will be loaned to you. Write for booking date.

SOLID METAL ADVANTAGES WITH CLAD STEEL ECONOMY

• • SPEED SCRAP TO THE MILLS TO MAKE MORE STEEL • •

A.W.S.-W.R.C. and I.I.W. appointments. The Board voted approval of recommendation of these National Officers for the appointment of a committee to be known as the A.W.S. Committee on I.I.W., with personnel as given below, and with exact scope to be determined in due course:

Chairman: The designated U.S.A. Vice-President of and Delegate to the I.I.W. (by action of A.W.S. Board of Directors).

Member: The designated U.S.A. Delegate to the I.I.W. (by action of A.W.S. Board of Directors).

Member: The designated U.S.A. Delegate to the I.I.W. (by action of W.R.C.)

Member: The President of A.W.S.

Member: The First Vice-President of A.W.S.

Member: The Second Vice-President of A.W.S.

Member-at-Large: Internationally active A.W.S. member—T. McLean Jasper (3-year term).

Secretary: The Executive Secretary of A.W.S. (nonvoting).

Brochure

The Executive Secretary reported that he had prepared complete rough draft of layout and text of brochure for executives in accordance with authorization at a previous Board meeting. Copy had been submitted for comments to the Chairmen and Secretaries of the Publicity, Technical Activities, Publication and Membership Committees; the Chairman and Director of the Welding Research Council; and to the Secretary of the Society. He said that copies were available at this meeting for Board members. He invited comments of the Board on the Brochure, and stated that such would be welcome if received before December 15th.

Adjournment

The meeting adjourned at 2:45 P.M.

Electronics Conference

An American Institute of Electrical Engineers' Conference on the Industrial Application of Electron Tubes will be held in the Statler Hotel, Buffalo, N. Y., on April 11 and 12, 1949. The conference will provide a means for electronic tube users to discuss their mutual problems with control equipment designers and tube manufacturers.

The program for the first day will include a technical session on the application of electron tubes in control and other industrial equipment, an inspection trip to the new Westinghouse Plant in Buffalo and a presentation of several papers by the users of electron tubes describing their operating experience and maintenance.

The second day will be devoted to a discussion of the items which the equipment manufacturers consider in designing control and other equipment-using tubes, followed by a technical session on the methods used by the electron tube manufacturers in building and rating tubes for industrial applications.

The conference is sponsored by the A.I.E.E. Subcommittee on Electron Tubes of the Electronic Committee, and the Subcommittee on Electronic Control of the Industrial Control Committee jointly with the Niagara Frontier Section of the A.I.E.E.

Movie Guide

The *Nema Movie Guide* is a compilation of 16-mm. films, both sound and silent, selected for their educational value in the electrical field. Included in this Guide are those films dealing with electrical subjects that formerly appeared in the *EMPIC Movie Guide*. Films previously listed therein but not appearing in the latest producers' catalogs were omitted.

The electrical films listed in the *Nema Movie Guide* are not exclusively those produced by electrical manufacturers. The films represent many industries, all interdependent upon one another for their products, but all jointly contributing to the glorious Electrical Age in which we live. It is hoped not only that the users of these films will enjoy the educational values they present, but that they may also see the vital part electrical industries play in promoting better living in America.

The compiler and the members of the National Electrical Manufacturers' Assn. are grateful to the many producers and distributors for their assistance in sending reviews, films and catalogs. In compiling this list of films they also drew heavily from film guides noted for their selection of films for educational purposes. Especially helpful in this regard was the *Educational Film Guide* published by H. W. Wilson Co., New York, N. Y., and the *Educators Guide to Free Films*, Educators Progress Service, Randolph, Wis.

Tempilstiks°

the amazing Crayons that tell temperatures

Simply mark your workpiece with the proper Tempilstik°. When the mark melts, the specified temperature has been reached.

A convenient method of controlling working temperatures in:

- WELDING
- CASTING
- FLAME-CUTTING
- MOLDING
- TEMPERING
- DRAWING
- FORGING
- STRAIGHTENING
- HEAT-TREATING IN GENERAL

Available in these temperatures (°F)			
125	275	500	1100
138	288	550	1150
150	300	600	1200
163	313	630	1250
175	325	700	1300
188	338	750	1350
200	350	800	1400
213	363	850	1450
225	375	900	1500
238	388	950	1550
250	400	1000	1600
263	450	1050	

$2 each

Also available in pellet or liquid form

FREE — Tempil° "Basic Guide to Ferrous Metallurgy" — 16¼" by 21" plastic laminated wall chart in color. Send for sample pellets, stating temperature of interest to you.

TEMPIL° CORP., 132 WEST 22nd ST., NEW YORK 11, N. Y.

We invite inquiries from reputable distributors interested in handling Tempil° products.

BLUE DEVIL E 6010
BLUEDAC E 6011
GRAY DEVIL E 6012
GRAY DEVIL No. 2 E 6012
GRAYDAC E 6013
BLACK DEVIL E 6020
RED DEVIL E 6030
BLACK DEVIL No. 75 E 7020

For Welds of Champion Caliber . . . Choose CHAMPION Welding Rods!

Mild Steel Electrodes

BLUE DEVIL	All Position, Reverse Polarity	A.W.S. 6010
BLUEDAC	All Position, A. C. Current	A.W.S. 6011
GRAY DEVIL	General Purpose, Poor Fit-up Straight Polarity	A.W.S. 6012
GRAY DEVIL No. 2 . .	General Purpose, Smooth Bead Straight Polarity Also A.C. Current	A.W.S. 6012
GRAYDAC	General Purpose, Smooth Bead Straight Polarity Especially designed for A.C. Current	A.W.S. 6013
BLACK DEVIL	Deep Grooves and Horizontal Fillets Straight Polarity	A.W.S. 6020
RED DEVIL	Deep Grooves, Reverse Polarity	A.W.S. 6030
BLACK DEVIL F. B. . .	Finishing Beads for Smooth Cover Beads	A.W.S. 6030

High Tensile Electrodes

BLUE DEVIL 85	All Position, Reverse Polarity	A.W.S. 7010
HY-LO	All Position, D.C. Reverse Polarity, Low Hydrogen Lime Ferritic	A.W.S. 7015
BLACK DEVIL 75 . . .	Deep Grooves and Horizontal Fillets	A.W.S. 7020
RED DEVIL 75	Deep Grooves, Reverse Polarity	A.W.S. 7030

Special Electrodes and Acetylene Rods

Stainless Steel Electrodes All Types

Electrodes & Acetylene Rods for Cast Iron Welding

Bronze and Copper Alloy Electrodes and Acetylene Rods

Tool and Die Electrodes

Hard Surfacing Electrodes

Aluminum Electrodes and Acetylene Rods

High Carbon, Alloy and Manganese-Nickel Electrodes for Rail Welding

Mild Steel Bare and Lightly Coated Electrodes

Mild Steel and High Carbon Acetylene Rods

CHAMPION Electrodes are Weld Rated Electrodes

WELDING ACCESSORIES

Chipping Goggles
Welding Machines: A.C. Transformer Types
Welding Goggles
Welding Cleaning Tools
Welding Clamps
Safety Clothing
Welding Gloves
Carbon Paste & Fluxes
Welding Cable Connectors
Welding Carbons
Carbon Plates
Welding Cable
Weld Spatter Eliminator
Electrode Holders

THE CHAMPION RIVET CO.

CLEVELAND, OHIO ★ East Chicago, Indiana

NEWS OF THE INDUSTRY

Annual Meeting—International Acetylene Association

Plans are being prepared for holding the next Annual Meeting of the I.A.A. at the William Penn Hotel, Pittsburgh, Pa., April 25 and 26.

Stress Analysis Meeting

The Spring Meeting of the Society for Experimental Stress Analysis will be held at the Hotel Statler, Detroit, Mich., on May 19, 20, 21, 1949.

Inquiries should be addressed to the Society for Experimental Stress Analysis, P. O. Box 168, Cambridge 39, Mass.

Purdue Welding Conference

This Welding Conference is sponsored by the Department of General Engineering and Division of Technical Extension with the cooperation of the Engineering Schools of the University and the neighboring chapters of the AMERICAN WELDING SOCIETY.

The conference is scheduled for Tuesday, Wednesday and Thursday, February 8–10th, inclusive. The general division of subject matter for the technical sessions is as follows:

Tuesday, February 8th—Resistance Welding

Wednesday, February 9th—Nonpressure Welding in Production

Thursday, February 10th—Welding Methods of Interest to Maintenance and Job Shop Operators.

Further information concerning either the conference or the exhibits may be obtained by addressing the Division of Technical Extension, 209 Service & Stores Building, Purdue University, Lafayette, Ind.

Lincoln Electric Incentive Payments for 1948 Total Over $3,800,000

Recently the Lincoln Electric Co., distributed $3,821,973 incentive payments to 1097 workers for the year 1948. These payments, as an average, double the income of every member in the organization, according to J. F. Lincoln, president of the Company, who, in making these payments, made the following statement:

"Our incentive program at The Lincoln Electric Co. has not only increased wages but also has reduced the selling price of its products to less than half that of comparable products on the market. That means that the motors and generators used for welding as well as the welding electrodes which we produce sell for less than half the price of similar motors, generators and electrodes manufactured and sold by other organizations for other purposes.

"The people in our organization who have accomplished this unique result are very proud of the skill and imagination which have made this record possible. Their increased financial income is only one of the benefits to them resulting from our incentive program.

"For the fiscal year 1948, the average product output per person on the payroll at Lincoln Electric is $29,748 compared with $6,895 as the average output per person of three other large electrical manufacturers. It will be seen that this is over four times greater than similar companies without incentives. When it is remembered that this record was made with a product selling for less than half of that of the usual manufacturer of similar equipment, the accomplishment is still more striking.

"If all industry should adopt a comparable incentive system, and it was as successful as in the case of our Company, the standard of living of all people would be quadrupled. All friction between so-called labor and management would disappear. The threat of communism, which is disturbing us so greatly, would be entirely removed and the satisfaction of all workers would be greatly enhanced."

Nooter Boiler Works Expands

As concluding phase of its $500,000 expansion program, The John Nooter Boiler Works Co., St. Louis, has purchased major items of equipment out of the Mount Vernon, Ill., plant of J. P. Devine Division, H. K. Porter Co., Inc. The Illinois shop has been closed by the parent Porter company in Pittsburgh.

Acquisition of the Devine equipment and its removal to St. Louis were announced by Robert J. Ryan, vice-president and general manager of the Nooter firm. Together with other new equipment recently installed or now on order, it provides facilities for fabricating the larger types of tanks and heavier pressure vessels used by petroleum, chemical, foods processing and other industries, Ryan said.

Included in the purchase from the Devine shop is a bending roll capable of processing steel plates up to 2 in. thick and to 20 ft. in width. The purchase also included Devine's car-bottom, or track-loaded, annealing furnace. The furnace will be used in stress-relieving metal products of dimensions up to 14 by 16 by 54 ft. Many other items used in fabricating heavy steel and alloy plate products were purchased from the Illinois shop.

Buildings recently completed include a metallurgical laboratory for testing welds and metals and for developing new techniques, an engineering office, a maintenance shop and a warehouse for equipment used by field crews in tank and smokestack erection.

Plans call for a new oxygen supply installation and an acetylene generation plant to accommodate increased welding and flame-cutting operations. Rail spurs add 1200 ft. of trackage for loading within the 8-acre plant area.

The expansion increases Nooter's employment capacity by 40%.

Burdett Builds Largest Oxygen Unit

Early in January, employees of the Burdett Oxygen Co. of Cleveland will watch new oxygen machinery go into operation. The center of interest will be the largest oxygen producing unit in Burdett's 25 years of business, being more than twice as large as any previous Burdett oxygen unit. It will cost over $150,000 and will produce more than 5,000,000 cu. ft. of oxygen per month.

The new unit will help meet the increasing demands of customers for oxygen, especially in steel mills and foundries. Here, new methods utilizing oxygen on furnaces, is enabling mills to produce 33⅓% more steel with the same facilities. Thus, this new oxygen unit will be effective in helping to relieve steel shortages. Most of the oxygen is handled in what is termed by the industry "bulk containers," not in the familiar gas cylinder. In addition to oxygen the new unit will also produce nitrogen and argon gas.

Resistance Welding Sales

Foreign orders for resistance welding equipment in November reached the highest level since April of this year, the Resistance Welder Manufacturers' Association reports, and were within 11% of foreign orders received during the entire third quarter.

Total shipments of resistance welding machines by members of the Association during November exceeded shipments for the same month last year by slightly more than 45%. T. S. Long, President of the Association reports. Shipments of electrodes, an excellent indicator of the wider extent to which resistance welding equipment is used, are also continuing at the highest levels in the history of the industry.

New Carbide Type Electrodes Developed for Severe Abrasion

A. P. I. drill pipe tool joints are built up with "Tungweld C" to resist severe abrasion experienced in drilling operations.

A worn dredge impeller is reclaimed by first building up the surface with "Fleetweld 5" and then hardsurfacing with "Tungweld F."

Life of this post hole auger is increased several times by applying a deposit of "Tungweld F" to the edge.

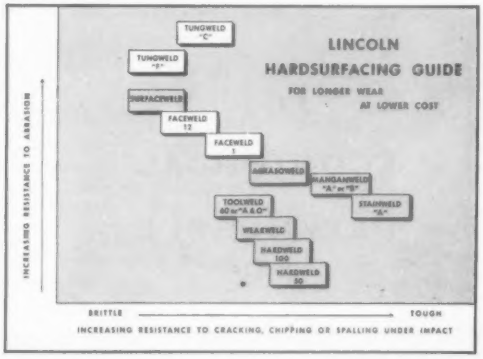
"TUNGWELD". The unusual wear resisting qualities of tungsten carbide make "Tungweld" electrodes particularly suitable on hardsurfacing applications where severe abrasion is encountered. "Tungweld C" deposits coarse particles of tungsten carbide in a tough alloy matrix. Under severe abrasion, the iron matrix wears away, continually exposing new, sharp tungsten carbide particles. The result is a self-sharpening edge ideally suited where a jagged, rough edge or surface is desired, as on earth-cutting tools. "Tungweld F" deposits fine particles of tungsten carbide where a thin, sharp cutting edge is required.

"FACEWELD". High resistance to metallic and non-metallic abrasion is obtained with "Faceweld" hardsurfacing deposits. This resistance is maintained even under higher temperatures and in the presence of corrosive atmospheres. Developed for hardsurfacing carbon, alloy and manganese steels, "Faceweld 1" forms a tough deposit for severe abrasion and moderate impact. "Faceweld 12" deposits are somewhat harder for increased resistance to abrasion.

Both "Tungweld" and "Faceweld" are coated tubular electrodes. The deposits are non-machinable and are finished by grinding.

The backplate of this chute is hardsurfaced with "Faceweld 12" providing increased resistance to falling aggregate.

Hardsurfacing Guide. **Quickly shows what electrode to use to best resist impact and abrasion. Size 8½" x 11". Write and ask for it.**



The above is published by **THE LINCOLN ELECTRIC COMPANY** *in the interests of progress.*

For further information, ask for Weldirectory for Hardsurfacing, Bul. 466. Write The Lincoln Electric Company, Dept. 92, Cleveland 1, Ohio.

Safety Posters

The 1949 Directory of Occupational Safety Posters, as prepared by the National Safety Council, is a 72-page directory containing 744 illustrations of two-three- and four-color posters, classified under 15 sections. A convenient index that quickly locates posters on specific accident hazards. Posters range in size from $8^1/_2$ x $11^1/_2$ in. to 10 x 12 ft. National Safety Council, 20 N. Wacker Dr., Chicago 6, Ill. Price, 50 cents.

American Optical Buys Stamford Property to Expand Research

Purchase of a 6-acre tract at Stamford, Conn., to create a research laboratory in the expansion of the research program of American Optical Co., was announced recently by Dr. R. Bowling Barnes, vice-president in charge of research and development.

The property includes a year-old building which will be completely remodeled for research purposes. Containing 13,000 sq. ft. of floor space, the structure formerly housed the Webb Offset Co.

Dr. Barnes said the research activities to be conducted in the Stamford laboratories "will supplement and be in addition to research by American Optical Co. at its headquarters in Southbridge, Mass., and at its scientific instrument division in Buffalo, N. Y. An entirely new scientific staff will be organized at Stamford to pursue work in fields related to the optical sciences and to scientific instruments, as well as research bearing directly on the company's products and processes."

The property is located off Hope St., Springdale, Conn., in the Township of Stamford, and was purchased from the Hope Street Realty Co.

"As a leader in its field," Dr. Barnes said, "American Optical Co. is expanding its long-established research program in order that it may add to its contributions to human knowledge and progress." While the fields of the company's interest have long been explored by scientists, there remains a vast uncharted area in these fields and in others related to them.

The purpose of the acquisition is to provide the most modern facilities for a group of scientists to pursue fundamental and applied research. Among the projects contemplated are basic scientific studies in physiological optics, plastics as optical components, glass chemistry, optical instrumentation, spectroscopy and microscopy.

Railroad Fair

The Chicago Railroad Fair, 1949 edition, will open on June 25th and run for 100 days—closing on October 2nd, Major Lenox R. Lohr, President of the Exposition has announced. The 1948 Fair opened on July 20th and continued until October 3rd, attracting more than two and one-half million visitors during the 76-day run.

While the Fair grounds have been winterized and inactivated, planning for the coming year has been proceeding full speed ahead with Lohr and the participating railroads in constant conference on how to make the second presentation even more interesting and attractive than was the initial show which won the acclaim of all who visited the Fair grounds.

The Exposition will occupy the same area on the lake front as did the 1948 version, for, in Major Lohr's conception of the development of the project, it is more important to improve the existing area to a point where everything possible is done for the comfort and entertainment of the Fair visitor than to expand merely for the sake of increasing the amount of ground occupied. His directives to his administrative assistants place all emphasis on "Better" rather than "Bigger."

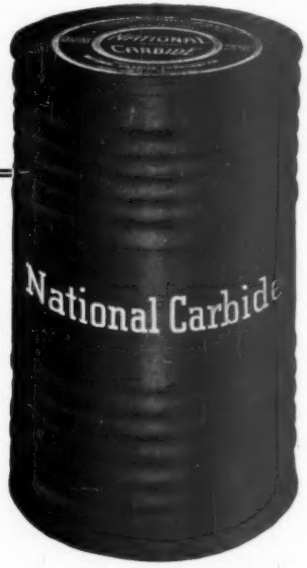
In some spots, enlargement of facilities cannot be avoided. Thousands were turned away from the grandstand at the brilliant spectacle "Wheels a-Rolling" which played to an audience of more than a million two hundred thousand. In view of the need for more seating space, plans are being made to enlarge the grandstand.

The erection of covered ways connecting the various exhibits on the grounds are being planned to protect visitors from sun and sudden showers; all roadways will be black-topped to add to walking comfort, and adequate comfort facilities will be provided to serve the Fair visitors.

Improved eating facilities will be avail-

National
Carbide
IN THE RED DRUM

EFFICIENT
ECONOMICAL
DEPENDABLE

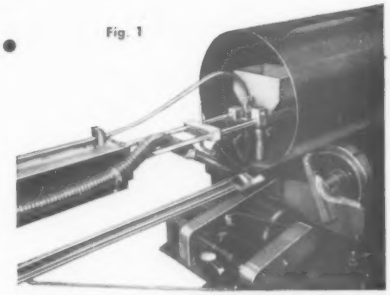


FOR WELDING and CUTTING
Use National Carbide in the Red Drum
Write us for information as to nearest available stock.
60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York 17, N. Y.

Berkeley Boom Welder

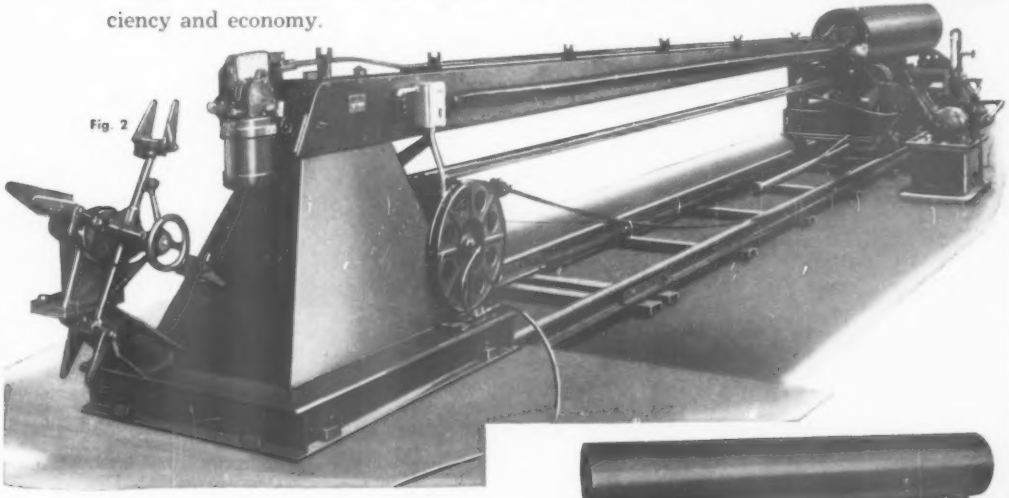
welds inside . . . outside . . . longitudinal or circular

Fig. 1



This universal Berkeley Welding Fixture can be used to do inside and outside longitudinal or circular seam welding with speed, efficiency and economy.

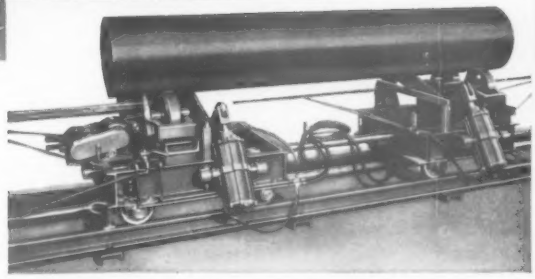
Fig. 2



Powered turning rolls* (fig. 2) for girth or circular seam welds, are rail mounted to permit longitudinal travel for seam welds. For inside welding, the rod feed is attached to the end of the boom as shown in the large illustration. For outside welding, the rod feed is positioned above the work.

*Available separately, or with Boom, as required.

Fig. 3



Berkeley Welding Fixtures and equipment have solved widely varied production welding problems for many manufacturers. It is probable that there is standard Berkeley equipment which will exactly fit your own problem.

If your production involves welding, a Berkeley fixture or Jig can speed your output while reducing costs.

PENN TOOL & MACHINE CO.

An affiliate of THE BERKELEY EQUIPMENT CO.

DANVILLE ILLINOIS

HIGH PRESSURE CYLINDER VALVES

for OXYGEN and HYDROGEN

Designed, tested and proved for high pressures and severe service.

Packing may be replaced with cylinder under pressure if necessary.

Fuse plug and bursting disc provide positive safeguard.

Bronze stem furnished as standard, also available with monel stem on special order.

for ACETYLENE

Listed by Underwriters' Laboratories.

Cadmium-plated steel stem with monel tip resists rust and wear.

Ball-nose seat construction assures positive shut-off.

for CARBON DIOXIDE

Available with diaphragm-type or packed-type construction.

Compact, rugged design for use with high pressures.

Equipped with bursting disc safety device.

*Reg. U.S. Pat. Office

REGO

The BASTIAN-BLESSING Company
4201 Peterson Ave. Chicago 30, Ill.

Pioneer and Leader in the Design and Manufacture of Precision Equipment for Using and Controlling High Pressure Gases

able, and to satisfy the expressed desire of thousands who could not be accommodated in the Fiesta Dining Car, at least four additional dining cars will be in service with the possibility that this number will be yet further expanded before the Fair opens.

The colorful Deadwood Central Railroad, which hauled hundreds of thousands of visitors up and down the grounds will be expanded to accommodate even greater numbers. A second train with a locomotive even more dazzling than Chief Crazy Horse will be added and will travel over the same tracks with a passing track added to permit passage of the trains.

Changes and additions to existing exhibits will be made and plans are being developed for outstanding new presentations.

As the 1948 Railroad Fair was the outstanding event in the United States entertainment world, so will be the 1949 version and even greater numbers of visitors from all over the country than came last year, can be expected to visit Chicago to attend the Exposition.

Combustion Engineering and Superheater Merge

Merger of two well-known power equipment manufacturers—Combustion Engineering Co., Inc., and The Superheater Co. —was consummated on December 22nd by approval of the stockholders of both companies. It became effective on Dec. 31, 1948, under the new name of Combustion Engineering-Superheater, Inc.

The original Combustion organization was founded in 1914, its products including Type E, Type B and Coxe stokers. Subsequently it absorbed other manufacturers of fuel burning equipment and several boiler companies, the latter including the manufacturers of Heine, Walsh-Weidner, Casey-Hedges and Ladd boilers. Two of these companies started in the field in 1884, and several others were organized prior to 1900.

The Superheater Co., was organized in 1910 as the Locomotive Superheater Co., designing and building superheaters for locomotive boilers. Later, it expanded its lines of products for locomotives and developed superheaters and other equipment for power plant boilers as well as marine and oil-country boilers.

Following World War I, both Combustion and Superheater were identified with major new developments in steam generation. Combustion was chiefly responsible for the commercial development of pulverized coal firing of boilers, water-cooled furnaces and completely integrated designs of steam generating units. Superheater pioneered in the development of superheater designs for higher steam pressures and temperatures. Both companies were identified with many of the installations which in the period from 1920 on set new standards of practice and performance.

Domestic manufacturing plants owned by the two companies occupy some 115 acres and are located at Monongahela, Pa.; Chattanooga, Tenn.; Chicago: East Chicago, Ind.; and St. Louis. Plants

STOCKS OF ALCOA ALUMINUM WELDING AND BRAZING RODS AND FLUX ALMOST AT YOUR ELBOW

When you need the best rods and flux for welding and brazing aluminum, telephone your nearby Alcoa Distributor at the number listed below. He is organized to give you immediate service on Alcoa Aluminum Rods and Flux. He also carries Alcoa Aluminum in its commercial forms. You'll find him a good man to know.

ALCOA DISTRIBUTORS

Atlanta, Georgia
J. M. Tull Metal & Supply Co., Inc.
Phone: WAlnut 3525

Baltimore, Maryland
Whitehead Metal Products Co., Inc.
Phone: LAfayette 2300

Boston (Cambridge) Massachusetts
Whitehead Metal Products Co., Inc.
Phone: TRowbridge 4680

Buffalo, New York
- Brace-Mueller-Huntley, Inc.
Phone: RIverside 2620
- Whitehead Metal Products Co., Inc.
Phone: CLeveland 1475

Charlotte, North Carolina
Edgcomb Steel Company
Phone: 4-9768

Chicago, Illinois
- Central Steel & Wire Company
Phone: REPublic 7-3000
- Steel Sales Corporation
Phone: BIShop 7-7700

Cincinnati, Ohio
Williams & Company, Inc.
Phone: CApitol 3800

Cleveland, Ohio
Williams & Company, Inc.
Phone: UTah 1-5000

Columbus, Ohio
Williams & Company, Inc.
Phone: MAin 3291

Dallas, Texas
Metal Goods Corporation
Phone: DIxon 4-3925

Detroit, Michigan
Steel Sales Corporation
Phone: TYler 6-3000

Houston, Texas
Metal Goods Corporation
Phone: BEacon 3-8881

Kansas City, North, Missouri
Metal Goods Corporation
Phone: NOrclay 3516

Los Angeles, California
- Ducommun Metals and Supply Co.
Phone: Kimball 0181
- Pacific Metals Company, Ltd.
Phone: PRospect 0171

Newark, New Jersey
Whitehead Metal Products Co., Inc.
Phone: BIgelow 8-8500

New Orleans, Louisiana
Metal Goods Corporation
Phone: CAnal 7373

New York, New York
Whitehead Metal Products Co., Inc.
Phone: WAtkins 4-1500

Philadelphia, Pennsylvania
- Edgcomb Steel Company
Phone: GArfield 3-6300
- Whitehead Metal Products Co., Inc.
Phone: BAldwin 9-2323

Pittsburgh, Pennsylvania
Williams & Company, Inc.
Phone: CEdar 0600

Portland, Oregon
Pacific Metal Company
Phone: BRoadway 0695

Rochester, New York
Brace-Mueller-Huntley, Inc.
Phone: GLenwood 0962

San Francisco, California
Pacific Metals Company, Ltd.
Phones: MIssion 7-1104
ENterprise 1-0800

Seattle, Washington
Pacific Metal Company
Phone: MAin 6825

St. Louis, Missouri
Metal Goods Corporation
Phone: GOodfellow 1234

Syracuse, New York
- Brace-Mueller-Huntley, Inc.
Phones: SYracuse 73-3341 9-6621
- Whitehead Metal Products Co., Inc.
Phone: SYracuse 5-4162

Toledo, Ohio
Williams & Company, Inc.
Phone: ADams 8101

Tulsa, Oklahoma
Metal Goods Corporation
Phone: 4-1175

ALCOA FIRST IN ALUMINUM

operated by subsidiary companies are located in Canada, England and France.

The companies do business outside the U.S.A. through representatives in the principal cities of Latin America and the Orient and through the following subsidiaries: The Superheater Co., Ltd., Montreal; Combustion Engineering Corp., Ltd., Montreal; Combustion Engineering de Mexico, S. A.; Combustion Engineering Limitada, Brazil; The Superheater Co., Ltd., London; The Superheater Co., Pty., Ltd., Sydney; Compagnie des Surch-aufleurs, Paris; and Stein et Roubaix, Paris.

The two companies became affiliated in 1933, and since then it has become increasingly evident that important advantages could be obtained by merging all operations under a single management. The new company will continue the world-wide activities of the present companies in the manufacture and installation of steam generating and associated products, and such equipment as chemical recovery units for pulp mills; flash drying systems for a wide variety of materials; sewage incineration system; mills for pulverizing products of the process industries generally; soil pipe and castings; domestic water heaters; and range boilers.

Officers of the new company are: Frederic A. Schaff, Chairman of the Board and Vice-Chairman of the Executive Committee; Samuel G. Allen, Chairman of the Executive Committee; Joseph V. Santry, President; Martens H. Isenberg, Executive Vice-President; Harold H. Berry, Vice-President in Charge of Finance. Vice-Presidents: Wilbur H. Armacost, George D. Ellis, Amaziah J. Moses, John S. Skelly, Otto W. Strauss, Donald S. Walker, Albert C. Weigel and Arthur Williams. Secretary and Asst. Treas., Irving B. Swigart. Assistant Secretaries, Thomas F. Morris and Francis J. Dolan. Assistants to Chairman, Thomas F. Morris and Frank R. Fitzpatrick.

Welded Barges

Bow end of the first barge in a fleet of six specially designed 240-ft. vessels for transporting dry bulk cargo, primarily sulfur and salt, on the Intracoastal Waterway and the Mississippi River and its tributaries, is shown in the accompanying photo, just before it was launched into the Ohio River at the Neville Island Shipyard of Dravo Corp. here. The articulated barges are being built for Butcher-Arthur, Inc., Houston, Tex., towing firm. With a 50-ft. rake end and a square stern, the welded steel, covered barges are to be used for high-speed two-barge towing operations. E. D. Butcher, Jr., vice-president of Butcher-Arthur is shown, right, on the bow of the barge.

WELDING CONNECTORS
Saxe System Welded Connection Units
for welded assembly

Saxe Units place in position and securely hold together structural parts to be welded.

As used in many welded structures they *eliminate all hole punching* producing an economical, rigid, safe and quickly erected structural frame.

"Write for 58 pg. Manual containing full engineering design information for welded structures."

J. H. Williams & Company
Buffalo 7, New York

G. D. Peters Company
Montreal 2, Canada
Canadian Representative

Buy "PROVEN FLUXES"
Years of GUARANTEED SATISFACTION
behind these GOOD
"ANTI-BORAX" FLUXES

Insist on them — Unequalled Quality

No. 1 Cast Iron Welding Flux
No. 2 Brazing Flux for Brass, Bronze, Steel, etc.
No. 4 Braz-Cast Flux for Bronze Welding Cast Iron
No. 5 & 8 Cast & Sheet Aluminum Fluxes
No. 9 Stainless Steel Welding Flux
No. 11 Tinning Compound
No. 16 Silver Solder Paste Flux

Mfg. By
ANTI-BORAX COMPOUND CO., INC.
Fort Wayne, Ind.

Clean big parts with the OAKITE STEAM GUN!

HERE'S an easy way to clean metal parts that are too large to be soaked in tanks or conveyed through washing machines.

Just use the Oakite Solution-Lifting Steam Gun to apply an Oakite cleaning solution under about 40 pounds of steam pressure. Oil, grease and other dirts vanish quickly, leaving the parts ready for inspection, assembly, further machining, overhaul or repair . . . . The same gun may be used with Oakite paint-stripping solutions.

FREE Write to Oakite Products, Inc., 18E Thames St., New York 6, N. Y., for illustrated folder F7338 containing more information about the various models of the Oakite Solution-Lifting Steam Gun and the many cleaning operations on which they are used with substantial savings in time and money.

OAKITE
REG. U. S. PAT. OFF.
INDUSTRIAL CLEANING MATERIALS • METHODS • SERVICE

Technical Service Representatives Located in Principal Cities of United States and Canada

WHY 4 TYPES OF KODAK INDUSTRIAL X-RAY FILM?

Because

Radiography in industry meets widely varying conditions—differences in density of materials, in size of objects, in type of radiation, and in the capacity of the X-ray equipment available.

No one film, or even two could give best radiographic results under all conditions. So Kodak provides industrial X-ray film in four types.

These afford the choice of speeds, contrast, and graininess that assure dependable, uniform results even under difficult situations.

TYPE M . . . provides highest contrast and exceptional detail under direct exposure or with lead foil screens—has extra fine grain, and speed is adequate for radiography of light alloys at average kilovoltage and for much million-volt work.

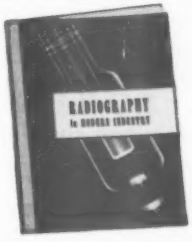
TYPE A . . . has high contrast with greater speed. For study of light alloys at lower voltage than practical with Type M, and at 1000 KV, for heavier parts than the finer grain film permits. Used direct or with lead foil screens.

TYPE F . . . offers highest available speed and contrast when exposed with calcium tungstate intensifying screens. Film has wide latitude with lead screen exposure either to X-rays or gamma rays.

TYPE K . . . has medium contrast. Chosen where speed is important and calcium tungstate intensifying screens are not used. Especially advantageous in studying heavy steel parts by gamma rays, and for the fastest X-ray diffraction exposures.

EASTMAN KODAK COMPANY
X-ray Division, Rochester 4, N. Y.

RADIOGRAPHY IN MODERN INDUSTRY



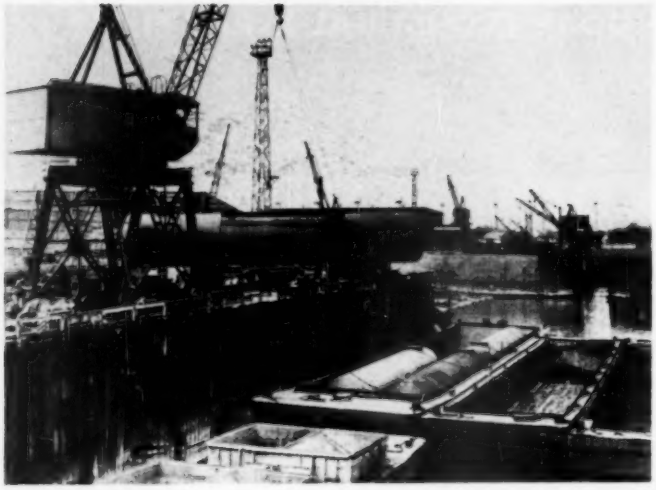
A wealth of invaluable data on radiographic principles, practice, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get your copy from your local X-ray dealer—price $3.

"Kodak" is a trade-mark

Radiography

. . . another important function of photography

Kodak



Rubber Lined Tanks

A 58,400-gal. rubber-lined tank, largest ever built for installation in a river barge, is shown being lowered into the hold of the first five specially designed barges for carrying hydrochloric acid on the Intracoastal Waterway and the Mississippi River and its tributaries. Dravo Corp. at its Neville Island Shipyard here is building the vessels for Dow Chemical Co., Texas Div., Freeport, Tex. Each barge carries four of the huge welded steel, rubber-lined tanks. They are the first vessels ever specifically designed and built for transporting hydrochloric acid.

A Million Aluminum Cans

Using two General Electric Type WP Inert-Arc Welders, the E. S. MacDonald Co., of Montreal, is completing an order which calls for 25,000 five-gallon aluminum cans a week for a period of ten months. These cans are to be used for the transportation of acid from Montreal to a rubber plantation in the Malay States. The Canadian General Electric Co. was consulted on the problem, and four days later a procedure was established for making sound, quality welds with 100% penetration.

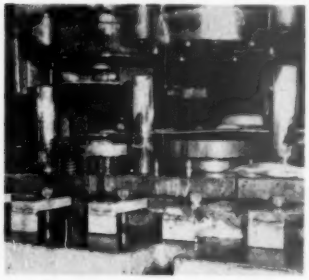
The material being welded is type 57-SH aluminum, 0.032 in. thick. A welding speed of about 26 in. per minute is maintained, using 5 liters of argon gas per minute at approximately 60 amp. Tungsten electrode, of $^{3}/_{32}$-in. diameter, is used.

Adjusting the electrode holder and travel carriage for making the longitudinal seam weld on the cans

Big Tool Steel Die Ring Back in Service in One Day

An automatic, four-operation, progressive type press, operating at 350 tons per impression, broke down when the die ring cracked in three places. The ring is made of high carbon, high chrome, air-hardened tool steel, with outside diameter of 16 and $3^{1}/_{2} \times 3^{1}/_{2}$ in.

To avoid a delay of three weeks while the Tool Department completed a new



die, this Ohio automotive manufacturing plant joined the breaks with Eutecrode 16FC, a low-melting, copper-base alloy of high tensile, for all steel welding. The die was restored to service at the end of one day and is still in use, producing over 700,000 plates since being repaired.

At the onset of the repair the break was ground out and lined up on the surface plate and found to be 0.005 in. off at the point of the worst break. The entire ring was preheated below 500° F., 1 in. from the weld area, and sides were tinned after fluxing. Breaks were joined, each break being completed before proceeding with next weld. The toolmaker found the entire die to be off only 0.003 in. when finished, and this was easily ground out, with no other after-machining necessary.

The die ring was then postheated to 400° F. for a short while to relieve stresses.

HAVING A METAL JOINING PROBLEM? Ask Us

Over 100 ALLOYS to solve Gas or Arc WELDING BRAZING SOLDERING Hard Surfacing Fluxing problems

Low Temperature EUTECTIC WELDRODS

"Eutectic Low Temperature Weldrods" can solve it for you the modern way by joining metals at low heat — avoiding distortion, stress, warping, overheating.

Write to sole manufacturer —

EUTECTIC WELDING ALLOYS CORP. DEPT.—C

40 Worth Street New York 13, N. Y.

Chicago, Cincinnati, Cleveland, Dallas, Detroit, Los Angeles, San Francisco, etc.

160 Field Engineers Everywhere to Help You

America's Welding Alloy Specialists

SPECIALIZING IN "BETTER-BUILT"

WELDING & SAFETY EQUIPMENT

FOR OVER 25 YEARS

There is a DOCKSON distributor near you. Name on request.

Write for our complete Welding and Safety catalogs.

Dockson CORPORATION

3639 WABASH • DETROIT 8, MICH.

Arc-welding Accessories

Pay off!

INCREASED PROTECTION

BETTER WELDING

LONGER LIFE

NEW COVER GLASS

All these features . . . at no extra cost

1. **Longer life use due to improvement of formula**
2. **Shop-tested by welders within our own plant**
3. **Controlled baking period**
4. **Careful attention to cleanliness**
5. **Treated on both sides**

For more detailed information, see your local G-E Arc-welding Distributor, or fill out the coupon and mail it today. We will send you a copy of the easy-reference G-E Arc-welding Accessory Catalog.

Copyright 1948, General Electric Co.

GENERAL ELECTRIC, Section B672-102
Apparatus Dept., Schenectady 5, N. Y.

Please send me, without obligation, G-E Arc-welding Accessory Catalog GEC-253.

Company.....

Name.....

Address.....

City..... State.....

ARC WELDERS • ELECTRODES • ACCESSORIES

GENERAL ELECTRIC

PERSONNEL

Big Three Appointments

The Board of Directors of Big Three Welding Equipment Co., Inc., wish to announce that C. K. Rickel has been elected President of the corporation; H. K. Smith, Vice-President; A. Smith, Secretary; C. K. Rickel, Jr., Treasurer; and J. H. Morgan, Assistant Secretary and Treasurer.

These changes were effective as of December 20th.

Hartbower Receives Navy Commission

Carl E. Hartbower, of 807 Xenia St., S.E., Washington, D. C., has accepted a commission as Ensign, Civil Engineer Corps, U.S.N.R., in ceremonies held recently at the Naval Reserve Training Center, Naval Gun Factory, Washington.

Mr. Hartbower, who is 27, is presently employed as metallurgist in the Welding Section, Naval Research Laboratory, Bellevue, D. C., where he conducts research on the effects of metallic-arc welding on metals used in Naval construction.

A graduate of Worcester Polytechnic Institute, he received a B.S. in Mechanical Engineering in 1943. Before entering the Naval service on May 25, 1945, Hartbower was employed for 27 months as a welding engineer at the Naval Gun Factory. He was then transferred to the Naval Research Laboratory, Bellevue, as an apprentice seaman in the inactive Naval Reserve. Two months later, he was called to active duty and promoted to Chief Petty Officer. He was honorably discharged on July 1, 1947.

Mr. Hartbower re-enlisted in the Volunteer Naval Reserve, Potomac River Naval Command on Feb. 16, 1948, as Chief Specialist in welding. He later became a member of the Organized Naval Reserve Construction Battalion when it was organized last spring as part of the Naval Reserve training program at the Potomac River Naval Command.

Ensign Hartbower is married and has three children: Carl, age 5; Annette, age 2; Daphne, age 1 month.

THE WELDING JOURNAL has published several of his articles, including "A Review and Summary of Weldability Testing Low-Alloy High-Tensile Steels"; "An Investigation of the Effect of Welding on the Transition Temperature of Navy High-Tensile Low-Alloy Steels" and "Auxiliary Tests on the Steels of I-Beams Tested in Flexural Impact at Columbia University."

A Record of Service

What is believed to be a unique record in the annals of American industry was marked on December 15th when Charles Lukens Huston began his 74th year of continuous service with Lukens Steel Co. Mr. Huston, grandson of Dr. Charles and Rebecca Lukens, for whom the company is named, now in his 93rd year, started with the concern on Dec. 15, 1875, as a clerk and bookkeeper in its offices. Today, as first vice-president, he is still spry of foot and keen of interest, and he walks to his office daily from his nearby home.

Mr. Huston studied first, the chemistry, and later, the metallurgy of iron and steel, thus supplementing his practical working knowledge of the metals, which proved of material assistance in the positions he subsequently held in the company and in the contributions he made to steelmaking, generally.

When Mr. Huston entered the employ of the firm in 1875, it had about 120 workmen and its plant occupied a site of less than a dozen acres. He has seen it pioneer and develop from a producer of first, iron and later, steel plate to a producer of steel plate specialties, employing upward of 5300 men and women, with a plant covering 600 acres.

Mr. Huston played an important part in this development. He is the patentee of several highly regarded inventions used in the manufacture of steel and he planned and designed Lukens' four-high 206-in. Mill, world's largest plate mill, and was largely responsible for the installation of the first head-spinning machine at Lukens, during the years (1882–1925) when he was in charge of plant operations. He was elected vice-president of Lukens in 1897, and from 1917 to 1925, he was vice-president and works manager. In 1925, he relinquished the position of works manager but continued as first vice-president, a position in which he still serves.

Mr. Huston was born in Coatesville July 8, 1856, the son of Dr. Charles Huston and Isabella Pennock (Lukens) Huston, granddaughter of Isaac Pennock, a founder of the business. In 1895, he was married to Miss Annie Stewart, of Savannah, Ga., and today their two sons are following in the footsteps of a line of iron and steel history makers. Charles Lukens Huston, Jr., is vice-president and executive assistant to the president, and Stewart Huston is secretary of Lukens Steel Co. Their only daughter, Ruth, is a missionary at Hyden, Ky.

Jewett Joins Battelle Trustees

Dr. Frank B. Jewett, formerly chairman of the board, Bell Telephone Laboratories, and formerly president of the National Academy of Sciences, has accepted an appointment as a member of the board of trustees of Battelle Institute, Columbus.

The new Battelle trustee is one of the outstanding research leaders of the era. A physicist and electrical engineer by training, he was associated with the American Telephone and Telegraph Co. and the Western Electric Co. in engineering posts during the period of the greatest technological developments in communications.

In addition to his business affiliations, Dr. Jewett has had an illustrious public service record. He has served as vice-chairman of the board of the Engineering Foundation, as chairman of the Division of Engineering and Industry of the National Research Council, and as president of the National Academy of Sciences. During World War I, his specialized abilities were utilized by several committees of the Navy and State Department, and during the recent war he was active in the work of the Office of Scientific Research and Development. He has been the recipient of numerous scientific honors and service awards, including the Edison and Faraday medals and the government's Distinguished Service Medal and Medal of Merit.

Dr. Jewett received his Bachelor of Arts degree in 1898 from the Throop Polytechnic Institute, now the California Institute of Technology. His doctorate work, leading to the Doctor of Philosophy degree, was taken at the University of Chicago. He also holds fourteen honorary doctor degrees.

Dr. Jewett began his professional career in 1901 as a research assistant to Prof. A. A. Michelson at the University of Chicago. He later served as an instructor in physics and electrical engineering at the Massachusetts Institute of Technology and in 1904 joined American Telephone and Telegraph as an engineer. Eight years later he became assistant chief engineer of Western Electric and by 1921 had risen to the office of vice-president and chief engineer. From 1922 to 1935, he served as operating vice-president of Western Electric. In 1925, he was appointed vice-president in charge of development and research of A.T. & T. and in the same year president of the Bell Telephone Laboratories. He served in the former capacity until 1944, and as president of Bell Telephone Laboratories until his appointment as chairman of its board in 1940.

Coleman Names Bussard Chief Process Engineer

E. A. Bussard has been appointed chief engineer of The Coleman Co., Inc., Wichita, Kan., manufacturers of gasoline pressure appliances and house heating equipment.

PAGE WELDING ELECTRODES AND GAS WELDING RODS

WELDING STAINLESS?

○

TO RESIST WHAT?

HEAT?
COLD?
IMPACT?
BENDING FATIGUE?
CORROSION?
WHAT **KIND** OF CORROSION?

○

NOW ONE MORE QUESTION:

Are you using the best electrode or rod for your purpose?

If you're not too sure, get in touch with your PAGE distributor. Either he knows or he can find out from the PAGE Field Service Man. And the PAGE distributor has a wide selection of Page-Allegheny Stainless Steel rods and electrodes, so that he can give you the one that will serve you best.

ACCO

TRADE MARK

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, Portland, San Francisco, Bridgeport, Conn.

PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

Get in touch with your PAGE Distributor

Bussard has been identified with the company for 24 years, and has held the position of welding engineer since 1940.

He is a member of the resistance welding committee of the AMERICAN WELDING SOCIETY and is past chairman of the Wichita Chapter. He is also active in the American Society for Metals.

Bussard's interest in welding dates back to 1925 when as a tank shop employee he was assigned to operate the first resistance welding equipment installed in the Wichita factory.

Upon joining the engineering department he prepared and directed the company's first welding training program. During the war he was a welding instructor in the production training program jointly sponsored by federal, state and local agencies.

OBITUARY

E. J. Rigby

Some of the founder members of the AMERICAN WELDING SOCIETY will learn with regret of the death of Edward Joseph Rigby of Melbourne, Australia, after three months' illness, in his 90th year. Mr. Rigby took an active part in the SOCIETY in its early years and was held in high esteem by all of his associates.

* * *

William D. Halsey

William D. Halsey, chief engineer of the boiler division of The Hartford Steam Boiler Inspection and Insurance Co., died suddenly at his home in West Hartford, Conn., December 9th.

Mr. Halsey was born in Philadelphia, Pa., on Feb. 28, 1890. He received a degree in Mechanical Engineering from Swarthmore College in 1912. Before his association with The Hartford Steam Boiler Inspection and Insurance Co. in 1920, Mr. Halsey was a design and maintenance engineer for the Sharples Separator Co. and the Baldwin Locomotive Works, and he served as professor of mechanical engineering at George Washington University for five years. During World War I, he was a technical adviser for the National Advisory Committee for Aeronautics.

Mr. Halsey joined the Hartford Steam Boiler Co. on June 15, 1920, as editor of its technical magazine, *The Locomotive*. In 1925 he was transferred to the engineering department with the title of mechanical engineer and was made assistant chief engineer of the boiler division on May 1, 1930. His promotion to chief engineer came in January 1943.

He was active in many engineering organizations, among which were the AMERICAN WELDING SOCIETY and the American Society of Mechanical Engineers. He had served the latter organization as a member of the Boiler Code Committee since December 1944.

Mr. Halsey joined THE AMERICAN WELDING SOCIETY in 1932. He was chairman of the Committee on Standard Qualification Procedures, which prepared the Standard Qualification Procedure in universal use today. He was also Chairman of the A.W.S. Committee on Pressure Piping which collaborated in the preparation of the welding requirements for the A.S.A. Code for Pressure Piping.

He served on a number of subcommittees of the A.S.M.E. Boiler Code Committee, among them being Subcommittee on Welding, Issuance of Symbol Stamps, Coordination, Power Boilers and Unfired Pressure Vessels. He was also a member of the A.S.M.E. Special Research Committee on vessels subject to external pressure and in addition served on many special committees.

Mr. Halsey was also the author of a number of papers presented at A.W.S. and A.S.M.E. meetings. He also wrote numerous articles for both the *Inspectors Bulletins* and *The Locomotive*.

* * *

W. F. Carson, Sr.

William Franklin Carson, Sr., of 616 Carpenter Lane, Mount Airy, a partner in the civil engineering firm of Carson and Carson, Commercial Trust Bldg., for nearly 30 years, died Dec. 11, 1948, in Germantown Hospital after a long illness. He was 61.

A graduate of Lehigh University in 1908, he was a member of the Pennsylvania Society of Professional Engineers, the Engineers Club of Philadelphia and the AMERICAN WELDING SOCIETY, Philadelphia Section, of which he was treasurer.

He was a member-at-large of the Philadelphia Council, Boy Scouts of America, for the past 20 years. He was chairman of the troop committee of Troop 29 and of Sea Scout Ship Martin, both with headquarters at the Summit Presbyterian Church of Mount Airy, of whose congregation he was a member. He was an honorary member of the Order of the Arrow, Unami Lodge, a Boy Scout unit.

A member of Theta Xi, he was a former president and vice-president of its alumni committee and aided in the founding of new chapters of the fraternity at Pennsylvania State College, the University of Pennsylvania and Lafayette College. A member of the Ocean City Yacht Club, he was one of the founders of the Great Egg Harbor Lightning Fleet.

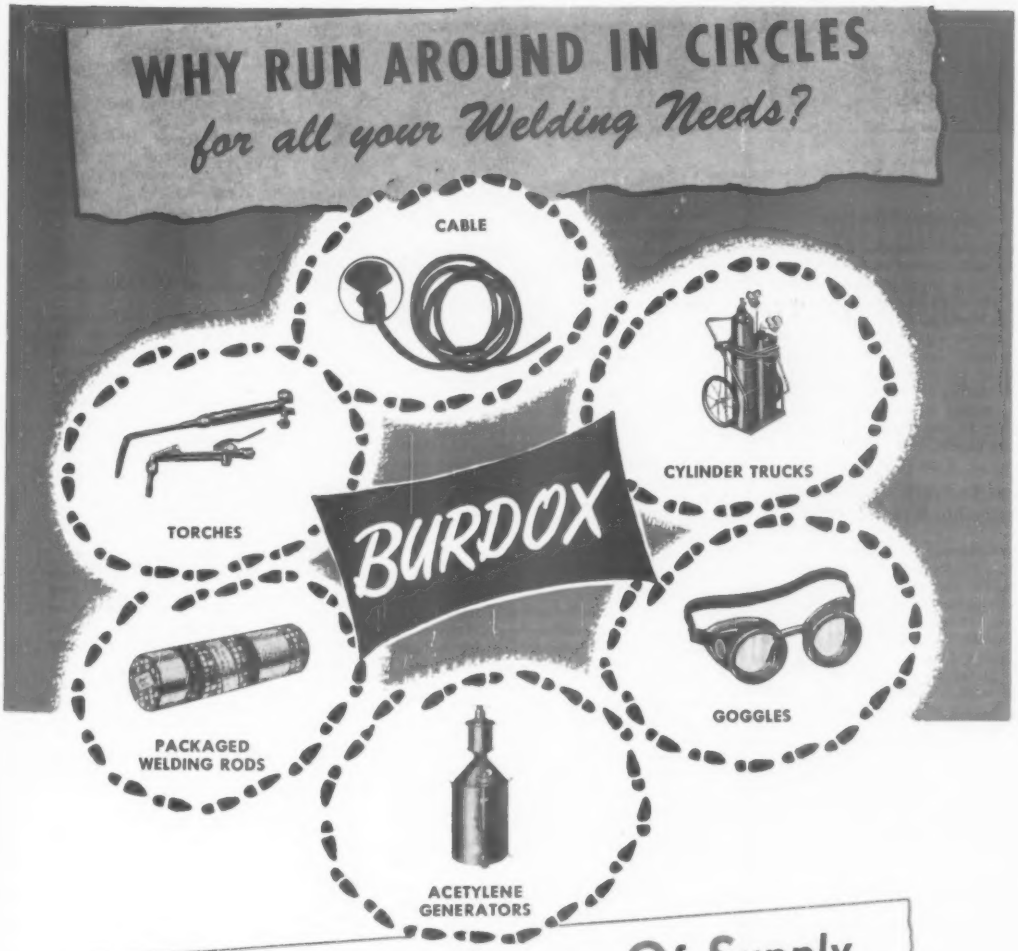
Besides his wife, Mrs. Marion LaRoche Carson, he is survived by two children, Mrs. Blanche C. Crooks and William F. Carson, Jr.; four grandchildren; three sisters, Mrs. Laura C. Burns, of Hatboro, Mrs. Emma C. Gibb, of Moorestown, N. J., and Mrs. Florence C. Nelms, of Ocean City, N. J., and four brothers, Walter C., his business partner; John T. and Robert J., both of Philadelphia, and Harold V., of San Diego, Calif.

PLACE YOUR ORDERS NOW!

The 1948 Bound Volume of The Welding Journal will be available within a couple of months. However, only a limited number will be prepared so that only those who place orders now will have them filled. Price $12.50.

This volume is a veritable encyclopedia of information. It will be bound in attractive imitation black leather covers and will contain a subject and authors index.

WHY RUN AROUND IN CIRCLES
for all your Welding Needs?



use this single Source Of Supply to save yourself TIME and MONEY

To get "the most for the least" out of any welding or cutting job, standardize on BURDOX products. They are produced by welding men who know from experience how to give you the best results . . . in the quickest time . . . at the lowest cost! Every BURDOX product provides the latest improvements, and offers outstanding quality at prices that mean real savings to you. BURDOX products are handled by leading welding distributors. Get acquainted with the hundreds of items in the BURDOX Line by sending for free new 68-page catalog.

THE BURDETT OXYGEN CO.
Established 1920
3302 LAKESIDE AVENUE
CLEVELAND 14, OHIO

THE BURDETT OXYGEN COMPANY
3302 Lakeside Avenue, Cleveland 14, Ohio
Please send free copy of new 68-page catalog.

FIRM _____

NAME _____

ADDRESS _____

CITY _____ STATE _____

NEW LITERATURE

Annual Meeting

The National Program Committee will hold its next meeting on Friday, February 11th. From the suggestions already received there is every indication that the Annual Meeting which will be held in Cleveland during the week of October 16th will be one of the most outstanding in the history of the Society from the point of view of quality of papers. Every member of the Society was provided with an opportunity to make suggestions for Annual Meeting papers.

How to Start and Operate a Profitable Welding Business

A new, 64-page booklet, *How to start and Operate a Profitable Welding Business* takes the reader through a step-by-step plan for starting and operating a job welding business. The book offers money-making suggestions for Job Welding Shops, Blacksmith Shops, Auto Repair Shops, Sheet Metal Shops, Machine and Tool Shops and Ornamental Iron Works. Each chapter covers an important part in the successful operation of a welding business, and numerous photographic illustrations show what opportunities are available for the aggressive welding operator. Send 10¢ (for postage and handling) to The Hobart Brothers Co., Hobart Square, Troy 1, Ohio.

Induction Heaters

A new catalog sheet issued by Electric Arc, Inc., 152 Jeliff Ave., Newark, N. J., offers a complete listing of induction heaters and control instruments for preheating before welding and stress relieving after welding.

The information contained on this sheet will be of particular interest to those firms who are interested in acquiring induction heating, stress relieving equipment and control instruments by purchasing or renting for field and shop heating of carbon and alloy steel pipe welds.

Manual of Die-Head Thread Cutting

This manual, by H. Schlarman, Former Manager, Thread Tool Division, Jones and Lamson Machining Co., Detroit Office, is a practical guide on threads and threading for the small-tool supervisors, the trouble men, the toolroom and screw machine foremen or operators as well as for the drafting room.

To the man engaged in any phase of thread cutting, it is an everyday reference book that identifies the threading troubles, explains their causes, and gives practical corrective measures. It explains the factors that comprise the chaser thread and their functions; the theory and practice of sharpening radial, tangent, or circular chaser; unusual adaptations of die heads and the setups; internal trips, their design and use; how to diagnose thread troubles visually and by gaging; and threading troubles, their causes and corrective measures required.

The *Manual of Die-head Thread Cutting* will help shopmen help themselves out of common thread-cutting troubles and eliminate machine down time occasioned by waiting for a manufacturer's service engineer.

Published by McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y. Price $3.50.

Electrode Holder

New 12-page Twecolog, Form No. 7, illustrates the complete line of Twecotong and Hol-Grip electrode holders, redhead ground clamps, cable connectors, terminal connectors, cable splicers, Twecolugs and carbon electrode holders. New six-bracket quantity price schedule and parts information is included. Contains valuable information about the maintenance and care of electric welding cables, connections, grounds and holders. Mailed free to those interested in the electric welding process. Write to Tweco Products Co., P. O. Box 666, Wichita, Kan.

Spectral-Transmissive Properties and Use of Eye-Protective Glasses

Conservation of eyesight is one of the foremost problems confronting safety engineers today. They have found that protection of the eyes from excessive exposure to radiant energy is as important as protection from mechanical injury. Information on the transmissive properties of most of the widely distributed makes of tinted lenses is now available in a new circular, *Spectral-Transmissive Properties and Use of Eye-Protective Glasses*, recently issued by the National Bureau of Standards.

This publication is the result of a study of the spectral-transmissive properties of about 200 glasses intended for use either as sun glasses or in special industrial operations where injurious amounts of radiant energy are present. Extensive consideration is given to elimination of glare, color distortion, use of glasses for night driving, standardization of glasses for outdoor and industrial purposes and the spectral-transmissive properties of glasses for use under various types and intensities of ultraviolet, luminous, and infrared radiation. It is proposed that sun glasses be grouped into three or four shades having luminous transmittances of 60, 35, 25 and about 10%, respectively, values that correspond roughly to those for the industrial shades numbered 1.5, 2.0, 2.5 and 3.0.

National Bureau of Standards Circular C471, Spectral Transmissive Properties and Use of Eye-Protective Glasses—34 large 2-column pages, 93 figures, can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of 20 cents a copy.

Nelson Standard M-G Studs

Illustrated 4-page price list contains dimensions and new low prices on the recently announced line of 60 standard M-G studs, specially designed for end welding with the Nelson automatic stud welding gun. Range covers diameters from 1/4 to 1/2 in. and lengths from 1 to 3 1/2 in., all available for immediate delivery. Bulletin also shows partial line of special-purpose studs. Nelson Stud Welding Div., Morton-Gregory Corp., Lorain, Ohio.

Inventory Listing

Inventory (32 pages) listing more than 1500 types, sizes and styles of Nelson flux-loaded studs available for immediate delivery. Can be obtained from Nelson Stud Welding Div., Morton-Gregory Corp., Lorain, Ohio.

New Transformer Catalog

In an attractive presentation, the Eisler Engineering Co., Inc., Newark, N. J., has just issued a new 26-page Transformer Catalog, No. TR-49, with over 135 illustrations covering in systematical arrangement the development and results of 28 years of management and specialized engineering experience in the design and manufacture of Transformers from 1/4 up to 400 kva. and potentials up to 15,000 volts, for every class of service.

Exemplified in numerous pictures and diversified applications are the general purpose specialty transformers for heating, welding, soldering, phase-changing, auto, testing, etc., and special transformer types of electronic devices, for Neon sign making, for the radio tube industry, etc.

The catalog is available free upon request on letterhead.

Gas Welding and Cutting

"Gas Welding and Cutting: A Practical Guide to the Best Techniques," by C. G. Bainbridge, M.I.Mech.E., M.Inst.W. Published on Dec. 6, 1948, at 15/- (postage 6*d*) by The Louis Cassier Co. Ltd., Dorset House, Stamford St., London, S.E.1., size D8vo (8 1/2 x 5 1/2 in.). 305 pages, 186 illustrations and 55 tables. Cloth bound with jacket.

A knowledge of welding cannot be acquired from textbooks alone, but a clear understanding of the underlying principles of methods and techniques involved is essential if a welder's work is to be entirely

All sub-assemblies of this 6-story galvanized iron ventilator stack were positioned for welding and turned toward welder. The operator held electrode slightly off-center in direction of rotation.

Good Welds on galvanized metal are quick and easy with Ampco-Trode 10

Profit from the experience of a large southern producer of galvanized and light-metal fabrications. This company found it could do a better job on a six-story galvanized ventilator stack — saving both time and money — by welding with Ampco-Trode 10.

The stack was made of 11-gauge galvanized iron. Welding (in preference to riveting) saved time and metal weight. Using 1/8" Ampco-Trode 10 electrodes (in preference to steel) gave them four additional advantages:

1. Burn-off of the coating adjacent to the weld was held to a minimum. The weld deposit itself is rust-proof.
2. The braze-welded bond is as strong and ductile as the galvanized iron base-plate.
3. Undercutting and resulting weaknesses were eliminated.
4. No back-up strip was required. The low melting point of the weld metal gave penetration sufficient to produce a small, uniform inside bead for a sound weld.

Other Ampco bronze electrodes such as Phos-Trode and Sil-Trode can also give you simple, successful welds (smooth, free from pitting and porosity) on galvanized pipe, depending on your service requirements. Ask your Ampco distributor for his recommendations on your specific needs today.

AMPCO

Ampco Metal, Inc.

Dept. WJ-2 • Milwaukee 4, Wisconsin

FREE! Complete information on Ampco-Trode welding electrodes!

Tear out this coupon and mail today!

Please send me a free copy of 8 pp. Bulletin W-17.

Name..... Position.....

Company.....

Street Address.....

City..... ( ) State.....

Sold in Principal Cities by Leading Distributors

POPULARIZING THE WELDING JOURNAL

The Publication Committee has instructed the Editor to add a special section in The Welding Journal each month, under some departmental heading as "Practical Welder and Designer." The nucleus of this special section will be one article each month of not more than four pages nor less than two which will give practical information on how to do a specific job, covering as many of the following topics as possible:

1. An exact procedure with illustrations of how to do the job.
2. Detail information as to design.
3. Full information on welding procedure or fabrication details.
4. Testing and inspection.

The Publication Committee has set aside $50 each month for payment of accepted articles of this nature. They should be written preferably by one who has followed the specific application in detail. Clear photographs or charts will be helpful and should be utilized.

successful. Today the scope of welding applications is almost unlimited and welding tends to become a matter of specialization, so that a comprehensive view of the whole range of equipment, methods and processes available is often difficult to obtain—hence this book.

This book is not intended to be a review of industrial employment of welding and cutting, except where it is desired to show particular point of procedure, and more attention has been paid to the desirability of providing essential and instructive illustrations of technique and methods.

The result is a textbook which provides a range of practical information not hitherto obtainable in one volume, and covering most of the applications of gas welding and cutting. It is a book for the practical welder, and for those responsible for gas welding and cutting operations involved in the fabrication, repair or maintenance of metal parts, or the installation of piping and other equipment. Throughout, the author has provided for needs of the student and instructor.

Arc-Welding News

Volume V, No. 4, *Hobart Arc-Welding News*, a 24-page booklet chock-full of interesting photographs and articles on welding from all over the country, is now being mailed.

This publication is mailed free of charge to anyone interested in arc welding and will be mailed immediately on request to the publisher, The Hobart Brothers Co., Troy 1, Ohio.

Svetsteknisk Handbok

Svetsteknisk Handbok, published by Bokförlaget Natur och Kultur, Stockholm, Sweden, 1947 (120 Kronor).

A copy of *Svetsteknisk Handbok*, the Swedish Welding Handbook, has recently been received in this country. It is a remarkable piece of work, from the viewpoint of excellence of technical content and manner in which the material is presented. It is published in the form of two leather bound volumes, each consisting of the order of 700 pages. Volume I contains thirteen chapters devoted largely to nomenclature, processes and metallurgy. Volume II contains sixteen chapters devoted largely to tests, weld stresses, properties of joints, standards and the various fields of welding application. The various chapters were written by some forty Swedish welding specialists under the editorship of H. Swedenborg and his associates, O. Forsman and E. Pelow.

In the main the chapter authors write in strict handbook style, classifying and arranging information and providing key diagrams, data and explanations practical and theoretical. Chapters 26 and 27 on welding standards are particularly good in this respect. These chapters describe Swedish standards for filler metal, weldable steels, and allowable stresses, and also the standards of Norway, Denmark and, to some extent, other countries. In this connection it may be pointed out that Swedish welding engineers place a good deal of reliance on a test specimen called the "drilled tensile specimen." Two $^{3}/_{16}$-in. holes are drilled through the butt weld of a transverse tension specimen. The tensile strength and elongation are used as specification values. In view of the importance attached to this specimen in Sweden, where it is regarded as a gage of behavior under stress concentrations, some research on it might be worthwhile here.

Two chapters deserving special mention are Chapters 8 and 9 by E. Helin and collaborators on welding metallurgy and the welding of steel. These two chapters cover nearly 200 pages and are a book in themselves. The treatment is fundamental and advanced, while the micrographs and macrographs used to illustrate the text are of a high order.

The fact that the handbook was published in 1947 explains the brief two-page discussion of inert-gas-shielded arc-welding, as well as the absence of data on one or two other more recent welding developments.

Since the *Svetsteknisk Handbok* is written in Swedish, it is of greatest interest to persons having a reading knowledge of that language. However, the many fine illustrations make it of great interest to all persons interested in welding. It makes a fine addition to any welding library.

Design for Welding

Design for Welding, published by The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio, contains over 1000 pages, $5^{1}/_{2}$ x $7^{1}/_{2}$ in., profusely illustrated with photographs, drawings, tables and cost data and bound in semiflexible simulated leather covers. Price $2.00, postage prepaid in the United States; $2.50 elsewhere.

A significant record of the progress of arc welding throughout all industry during the postwar years is contained in the new book, *Design for Welding*, just published and made available by The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

The book is composed of abstracts of 82 award papers in the recent Foundation "Design-for-Progress" Award Program. The papers were selected and edited by Prof. R. S. Green, Acting Chairman of the Department of Welding Engineering of the Ohio State University, Columbus, Ohio.

In the preface of the book Professor Green states that he has prepared the book with the purpose of making available a record of representative welded designs. He has placed emphasis on projects produced and in operation with the objective of providing engineers and industry generally with a variety of ideas which may be adaptable to their own products or structures. The book contains a liberal presentation of cost data on the various designs which afford a sound means of making a comparative study of methods.

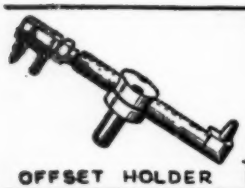
Professor Green also calls attention to the present trend in the development of welding applications as evidenced by these papers. More papers speak of welding as used on production items rather than as applied to single units. Many of the papers describe the application of welding directed to the reduction of manufacturing costs and the improvement of quality and performance.

This interest in improving existing welding applications, Green points out, is the natural outcome of the widespread use of welded construction in many fields.

Papers included in the book, *Design for Welding*, are classed into the following categories: Aircraft, Automotive, Railroad, Watercraft, Containers, Furniture, Structures, Machinery and Welderies. Each section contains papers describing outstanding accomplishments in that particular field. The Machinery and Structures sections are especially strong and the quality of the papers evidences the advance in design in these fields. The book contains over 1000 pages of text material, profusely illustrated with photographs, drawings, tables, as well as cost data.

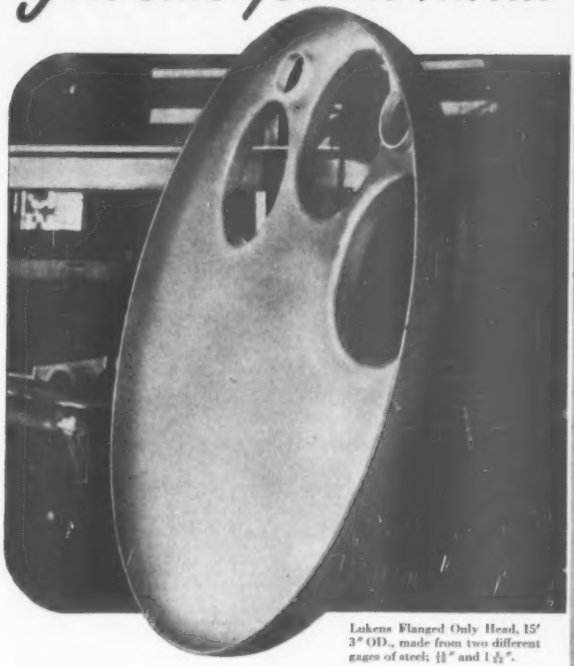
Assisting Prof. Green were associate editors Prof. Douglas C. Williams and Prof. Charles B. Smith, both of the Ohio State University, in addition to numerous consulting editors chosen from industry.

Design for Welding is bound in semiflexible simulated leather covers and is available from The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio. Price $2.00, postage prepaid in the United States; $2.50 elsewhere.

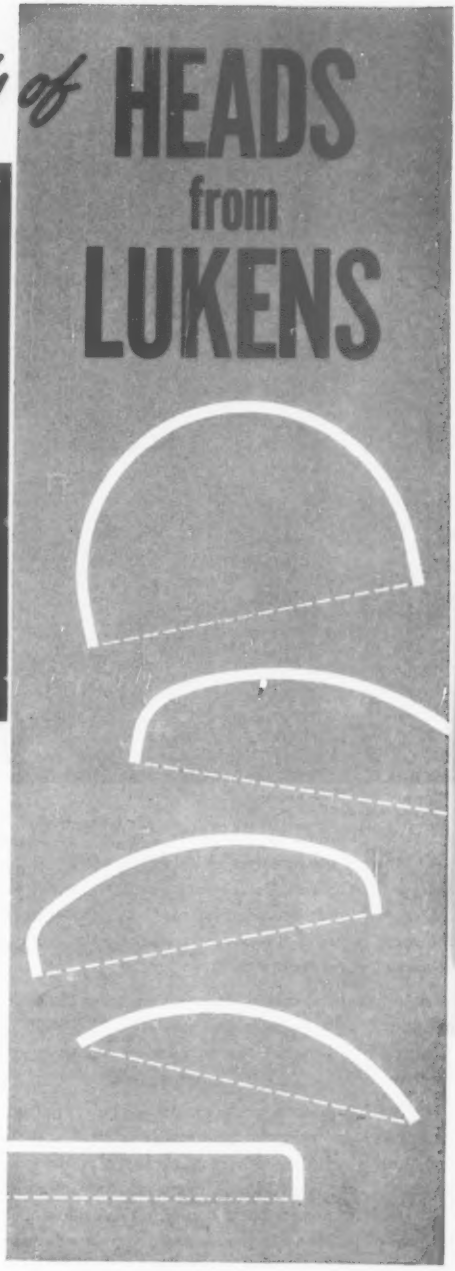

"ELECTROLOY" for RESISTANCE WELDING
Butt
Flash
Spot
Seam
Projection
ELECTROLOY
Catalog and prices on request

OFFSET HOLDER
THE ELECTROLOY CO. INC. 1600 SEAVIEW AVE. BRIDGEPORT, CONN. WELDING ROLL

You can get all kinds of HEADS from LUKENS



Lukens Flanged Only Head, 15′ 3″ OD., made from two different gages of steel; $\frac{11}{16}$″ and 1 $\frac{5}{16}$″.



Heads four inches in diameter to over twenty feet; thicknesses up to six inches—Heads of any shape, from single-gage flat heads with straight flanges to complex multiple-gage heads, complete with flues and manholes—Heads of any commercial metal; carbon and alloy steels, including stainless, nonferrous metals and the widest range of clad steels available anywhere. Lukens makes them all!

Many sizes of Standard and ASME Flanged and Dished Heads are in stock, ready for prompt shipment. Hundreds of dies are available for making other styles and sizes, usually permitting us to ship heads within a short time after your order is received.

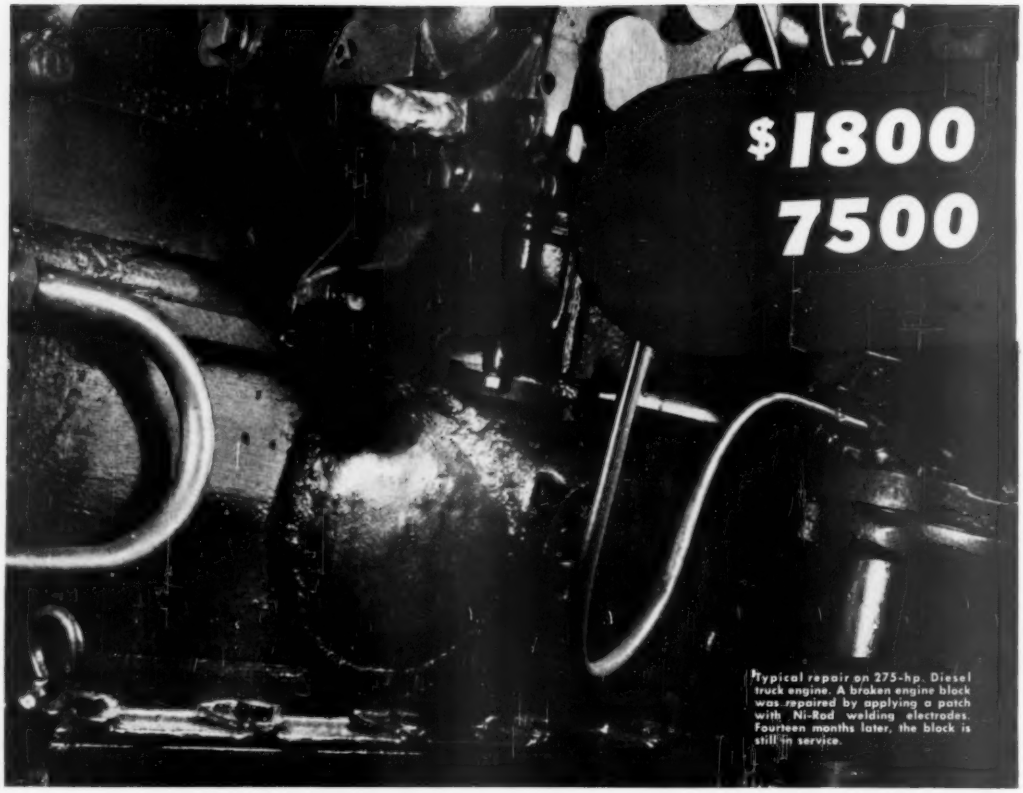
3,868 Heads are described in Lukens Catalog No. 1; stock heads, in Bulletin 433. For copies and for a quotation on your head requirements, write Lukens Steel Company, 407 Lukens Building, Coatesville, Penna.

LUKENS HEADS ★

"Head Work", a 16mm motion picture in sound and color, on spinning and pressing of Lukens Heads is available without charge. Running time: 27 minutes. Write for a booking date.

FOUR INCHES TO OVER TWENTY FEET IN DIAMETER

• • SPEED SCRAP TO THE MILLS TO MAKE MORE STEEL • •



Typical repair on 275-hp. Diesel truck engine. A broken engine block was repaired by applying a patch with Ni-Rod welding electrodes. Fourteen months later, the block is still in service.

IN the open-pit nickel mines at Copper Cliff, Ontario, Diesel trucks haul 32-ton ore loads up steep, winding roadways. After several thousand hours of this severe service, failures develop in castings and engine parts.

A serious type of failure is the cracking of cast iron cylinder blocks. New engine blocks cost $644.09 each ... a price that makes the prospect of repairs very attractive.

In the past, damaged blocks have been repaired by oxy-acetylene welding, a relatively critical and time-consuming process. But recently, repairs have been made with metal-arc welds, using Ni-Rod* electrodes. This technique has been completely successful, and the use of Ni-Rod electrodes has given excellent weld quality and has cut welding time.

Here are three typical case reports on repairs made with Ni-Rod:

"1. Block broke in crank chamber after 9381 hours of service. A patch was welded in with Ni-Rod. Since the repair, the block has operated 2064 hours and is still in good condition. Cost of welding was $12.75.

"2. Crank shaft failed after 1746 hours. The broken end engaged the main bearing shells, turning them in the block, heavily scoring the saddle. Repairs were made by machining the bearing area to .100-inch oversize, building up with Ni-Rod, and finally machining to correct size. This prolonged the engine life by 4087 hours. Cost of the entire repair was $40.60.

"3. Crank shaft failed after 4540 hours, causing damage similar to that described in Case 2, above, and was repaired the same way. The engine is still in operation 1369 hours after the repair. The cost of repair was $42.50."

SAVED . . .
HOURS MORE SERVICE
from truck engines repaired with NI-ROD

The three blocks described have a total replacement value of $1,932.27. Subtracting the repair costs, there is a net saving of $1,836.42, and a gain of more than 7520 hours of operating service.

Maintenance stories such as these...three of hundreds in our files...show why 4 out of 5 shops re-order Ni-Rod, once they've tried it. If you are not yet familiar with Ni-Rod's outstanding advantages, why not order a package today? Your nearest INCO distributor stocks Ni-Rod in 3/32", 1/8", 5/32", and 3/16" diameters.

Send for your free copy of: *"NI-ROD—A New Electrode for Any Cast Iron Welding."*

The Frood Stobie Mine, Copper Cliff, Ontario, operated by The International Nickel Company of Canada, Ltd.

One of the Diesel-powered trucks used for ore hauling at the Frood Stobie Mine. The truck maintenance department has standardized on Ni-Rod electrodes for cast iron repairs.

HERE'S WHAT NI-ROD GIVES YOU

in performance

- Stable arc in all positions
- Smooth bead contour
- Excellent wash
- Easy slag removal
- Preheating seldom required
- Works on both AC and DC

in weld quality

- High-strength deposit
- Easy machinability
- Thorough fusion
- Freedom from cracks and porosity
- Close color match

in usefulness

- General repair and maintenance of cast iron parts, including build-up of worn surfaces
- Quick remedy for minor flaws in new castings
- Correction of machining errors
- Assembling cast iron to steel

EMBLEM OF SERVICE
INCO NI-ROD TRADE MARK

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street, New York 5, N. Y.

*Reg. U. S. Pat. Off.

NEW PRODUCTS

Internally Fluxed Copper Gas Welding Rod

A new internally fluxed gas welding rod for welding deoxidized copper is offered by Arcos Corp., Philadelphia, Pa.

The self-fluxing property of "Silbrax" prevents repeated rod oxidation and hence faulty weld metal. Because "Silbrax" is fluxed internally, the heat is applied first to the metal and then transmitted to the flux. "Silbrax," therefore, keeps a proper balance at all times between melting metal and flux.

"Silbrax" is also used as a filler rod for carbon and inert arc welding.

Samples will be sent upon request to Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa.

Farm Welder

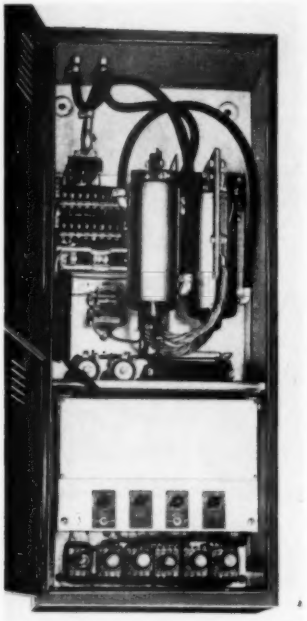
A new small welder of 5 to 180 amp., suitable for the farm, home, garage, blacksmith shop, plumber, sheet metal shop, farm implement dealer, job shop, machine shop and factory maintenance, has been placed on the market by the US Electric Welder Corp., 1258 Dorr St., Toledo 7, Ohio.

The compactness of the US Model 200 Arc Welder makes it convenient and easy to handle around any type of job. It measures only 21 in. long, 14 in. wide and 22 in. high. This welder only draws 30 amp. from the power line and its stepless control provides more than 200 heat selections. It operates on single phase or on one leg of two- or three-phase lines.

Electronic Spot-Welder Control

Class 8992 electronic combination units are the latest addition to Square D Company's complete line of resistance welder control. These new electronic controls include N.E.M.A. type 3B timers and ignitron tube contactors for complete control of spot welders.

The timer uses no sequencing relays and will operate at repeat speeds of over 400 welds a minute. The simple six-tube circuit cancels out operating delays of valve and firing relays. Hold time settings down to one cycle make it possible to get faster mechanical operation of the welder.



Regulated D.-C. timing circuits insure accuracy for line voltage variations as great as plus or minus 10%. Firing relay operation is coordinated with A.-C. line supply to give a consistent starting point for each weld and to insure full cycles of welding current. This feature improves performance by avoiding high transient currents and transformer saturation.

The timer can be connected for either common or separate control supply of 115, 220 or 460 v., 50 or 60 cycles. The separate contactor panel accommodates sizes A, B or C ignitron tubes.

For further information regarding this control, write the Square D Co., 4041 N. Richards St., Milwaukee 12, Wis. Request Bulletin 214.

450-Watt Thermo-Grip Soldering Set

Ideal Industries, Inc., Sycamore, Ill., announces a new light-duty "Thermo-Grip" soldering tool that operates on the resistance heating principle.

Touching the work with the soldering tool completes the secondary power circuit and causes the part touched to heat almost instantly. A handy thumb switch permits close heat control. The "Thermo-Grip" conserves power, drawing current only when the soldering tool is in direct contact with the part to be soldered. It is ideal for use in inaccessible places and inflammable surroundings.

A complete set of soldering tools or attachments for handling all types of work includes a "plier" attachment for sweating and unsweating copper tubing, soldering lugs, terminals and other work of that type; a "fork" attachment with two 3 in. electrodes for reaching into restricted places such as in switch boxes, electrical tools and equipment; a "pencil" attachment with one 3-in. carbon electrode for spot soldering and light seam soldering.

Hy-Lo Electrode

The Champion Rivet Co., Welding Division, Cleveland, Ohio, announce their new Hy-Lo Electrode A.W.S. E7015 for the welding of high-sulphur, high-carbon, low-alloy high-strength and hardenable steels.

Hy-Lo can also be used to weld parts that are to be galvanized or porcelain enameled, steel of doubtful analysis, manganese or spring steel to mild steel, locomotive frames and flexible staybolt sleeves, etc.

In addition to this Hy-Lo with excellent X-ray qualities and physical properties far exceeding A.W.S. Class E7015, Champion also supplies this Electrode in the higher tensile ranges of A.W.S. E8015, E9015 and E10015.

If you have hard-to-weld steel jobs or weld failures with other types of electrodes, we suggest that you try Champion Hy-Lo.

ARCALOY TYPE 316-ELC

One of four Fractionating Towers welded with New Arcaloy Type 316-ELC electrodes.

An Alloy Rods Co. customer for 10 years, the Steel and Alloy Tank Co. of Newark, N. J., needed a type 316 analysis electrode with carbon deposit of .03% max. in the weld! The result is the new Arcaloy Type 316-ELC—which produces stainless steel welds with the *lowest carbon* deposit in welding history!

This new electrode was used in the construction of four fractionating towers (one shown here) . . . each 59 feet long, 6 feet in diameter, with ¼ inch walls. With Arcaloy Type 316-ELC, the welds had increased high resistance to corrosion . . . extremely important in this application.

Arcaloy Type 316-ELC is the result of Alloy Rods Co.'s continuing research and development which helps you by constantly *improving* standard electrodes and *developing* new and better ones. For more specific information on Arcaloy Type 316-ELC, or any other Alloy Rods Co. electrodes . . . for welding stainless steel, mild steel, cast iron, tool steels and various alloys, write today to: Alloy Rods Co., Department C-3, York, Pennsylvania.

* Extra Low-Carbon.

Look for the *FLAMING-ARC* Trademark

Alloy Rods Co.
York, Pa.

Chipping Tool Has Replaceable Bits

A new weld chipping hammer is announced that makes replacement of worn bits practical for the first time. "Re-Bit" has been adopted as the model name.

Atlas Welding Accessories Co., 707 E. Lewiston, Detroit 20, Mich., manufacturers of the new tool, advise that no balls, springs, screws or clamps are used and that a simpler taper locks both bits securely in the head in any position desired.

Redesign of the blades has been incorporated to provide better visibility, longer life, easier access to tight spots and a wider chipping edge.

"Re-Bit" Tomahawks are offered in 12- and 16-oz. weights with a choice of Flex-o-steel or wood handles.

Electrode for Welding Monel, Monel Clad, and for Overlaying Steel

Arcos Monend 806 electrodes produce X-ray quality welds on Monel, Monel clad and steel. Monend 806 eliminates the necessity of depositing a buffer layer of nickel.

Monend 806 has a spray type arc of excellent stability, which facilitates all-position welding. Free-bend specimens exhibit high elongation values, normally 50% or higher; typical weld metal yield strength is 42,500 psi. and tensile strength 75,500 psi.

Further details and samples will be sent upon request to Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa.

Brush on Multi-Pic Weld Hammer

A unique type of wire brush for whisking away loosened slag, oxides and rust from welded parts has recently been incorporated into the handle of the Bernard Multi-Pic Weld Cleaning Tool. Especially designed to reach into the deepest corners and crevices, and made from sturdy crimped, oil hardened wire, this new brush is exceptionally long and can be used to the very tip end. The handle of the Multi-Pic tool contains a cavity into which the Repeater brush is inserted. To adjust the brush as wear progresses, a flat head screw which holds the shank of the brush

is removed, another usable portion of the brush drawn out to the next adjustment, and the screw again inserted. Five such adjustments are provided and hence the brush will wear five times longer than an ordinary brush. New Repeater Brushes are available packed three to a box.

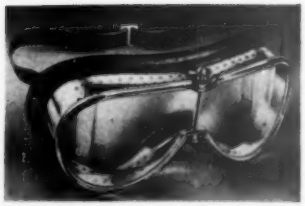
Multi-Pic Weld Hammers with Repeater Weld Cleaning Brushes are manufactured by Bernard Welding Equipment Co., 741-743 E. 71st St., Chicago 19, Ill.

Goggle Cushions

The AO Panoram goggle is now available with rubber cushions to provide extra wearing comfort, American Optical Co. of Southbridge, Mass., announces.

The company states the cushions are molded to the exact shape of the Panoram eyecup and can be slipped into place very easily—with no need for stapling, sewing or cementing. Once in place, they stay, but can be replaced in a few seconds.

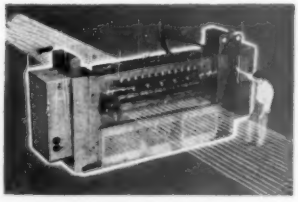
Made of soft, pliable, nontoxic, Neoprene sponge rubber, the cushions assure extra protection against dust and flying particles.



The company also announces a new, pouch-type plastic case to protect Panoram goggles from scratches, dust and dirt when the goggle is not in use. The case has heavily stitched, reinforced edges and a flap with a snap hook. Large enough to completely enclose the goggle, the case is so flexible that it can be tucked away in a worker's pocket or other small space.

Wire Welding Machine

An outstanding example of a special production machine was developed by pooling the knowledge of a wire fabrication manufacturer and the practical use of resistance welding.



This machine, designed and built by Sciaky Brothers, Inc., of Chicago, contains 12 welding pressure heads with die blocks, each arranged for welding one or more wires simultaneously so that logitudinal wires of any spacing from $^1/_{16}$ in wire spaced $^1/_4$-in. center to center, to $^5/_{16}$-in. wire spaced $^1/_2$-in. center to center, and a maximum spacing of 12 in. in each case, may be welded with no adjustment of the electrode or the heads.

By use of the Sciaky patented "Three-Phase" system, uniform current distribution is obtained over all the die blocks and a direct weld is made which permits the loading of the cross wires from above.

SPOT WELDERS

OF ALL TYPES
SIZES 1/4 TO 300 KVA.
FOR MANUAL, AIR, MOTOR, OR ELECTRONIC OPERATION
also BUTT, ARC, and GUN WELDERS

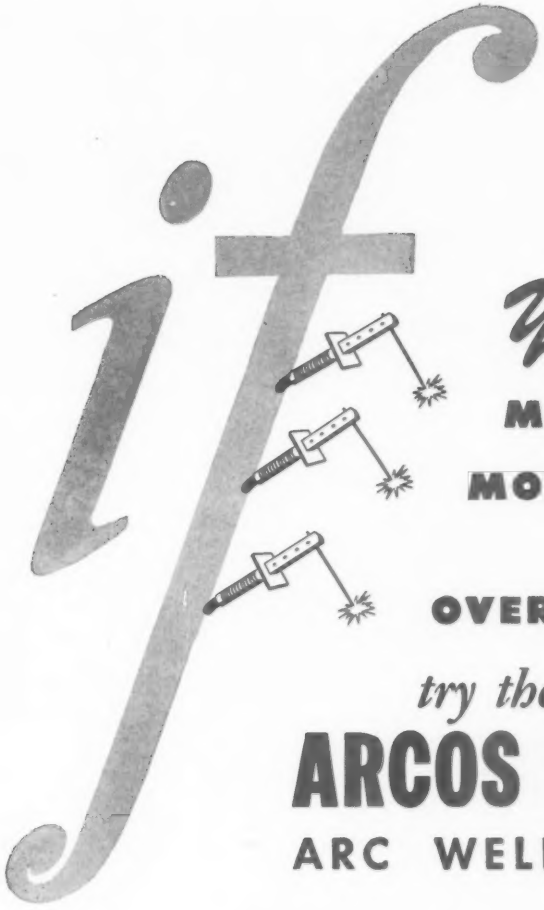
TRANSFORMERS
For Furnaces, Lighting Distribution, Power, Auto Phase Changing Welding, and Special Jobs.
AIR OIL, and WATER COOLED.
Sizes 1/4 to 300 KVA.

CHARLES EISLER
EISLER ENGINEERING CO., INC.
779 South 13th St. (Near Avon Ave.) NEWARK 3, N. J., U.S.A.

TIP CLEANING DRILLS
Mounted in Knurled
BRASS Handles

LARGE STOCK
PROMPT DELIVERY

DISTRIBUTORS WANTED
NEW MEXICO STEEL CO.
Box 1546, Santa Fe, N. M.



if You Weld

MONEL...

MONEL CLAD

or

OVERLAY *with* MONEL

try the new improved

ARCOS MONEND 806

ARC WELDING ELECTRODE

CONSIDER THESE UNUSUAL PROPERTIES

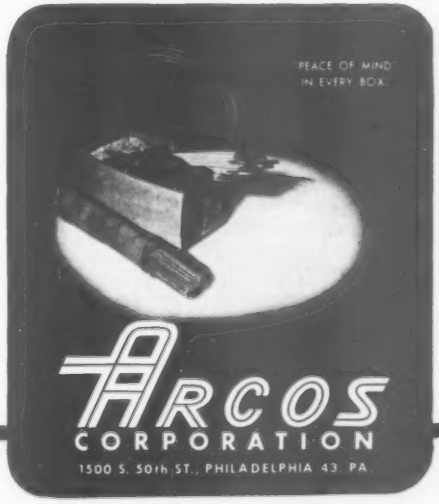
- **X RAY QUALITY WELD METAL**
- **TYPICAL WELD METAL AS WELDED**

Yield Strength	*42,500 psi.*
Tensile Strength	*75,500 psi.*
Elongation in 2"	*42%*
Reduction of Area	*60%*

- **MONEL CLAD (½"—20% CLAD)**
  Typical Free Bend Elongation—53.7%
- **OVERLAY (¾" MILD STEEL BASE)**
  Typical Free Bend Elongation—51.5%

SEND FOR FREE SAMPLES

Address your inquiries to Dept. S.



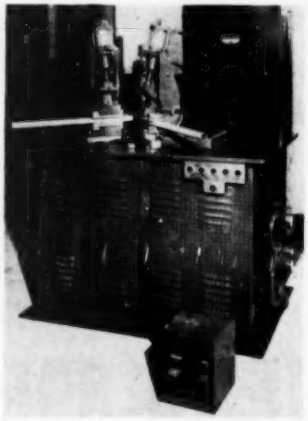
The cross wire is loaded automatically and the longitudinal wires are indexed automatically with an adjustable spacing.

Because of the "Three-Phase" system, the maximum power demand is greatly reduced and balanced on the three phases of your power supply with a power factor of at least 85%.

Flash Welder

A new development in a push-button flash-butt welder especially designed for pipe and tubing.

Welding heads are swivel mounted so that two pieces can be butt welded or flash-butt welded at an angle. The ends are cut square for both types of welding.

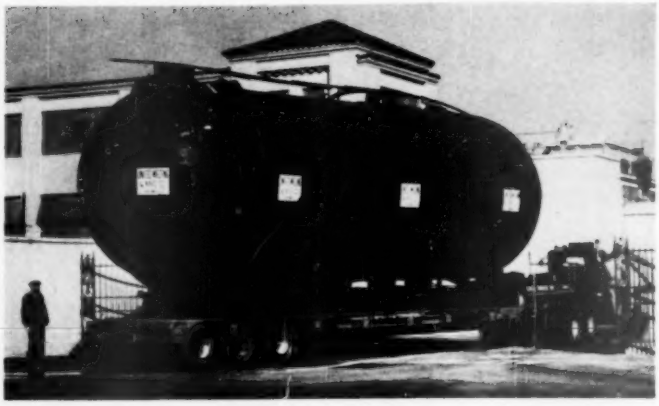


Action is entirely automatic and is controlled by micro switches. One button does all the work, although, for testing purposes, the movements can be initiated separately.

Each clamping jaw has its own foot valve and air cylinder with pressure regulater. The upset action has its own supply and controls.

Transformer has a number of heat tap settings and is fully protected so that upset metal cannot reach it.

Manufactured by Rex Welder and Engineering Co., Kansas City, Mo.



Jumbo Pressure Cooker

Jumbo Pressure Cooker

As big as a box car, this jumbo version of the housewife's pressure cooker has been shipped to Firestone Tire and Rubber Co. of California. It measures 43 ft. in depth and 12½ ft. in diameter. In it will be processed the largest self-sealing rubber fuel cells now being a development of Firestone Tire and Rubber Co.

Not only is this the largest pressure vessel of its type to be built in the West, it is one of the world's largest rubber curing chambers. Of A.S.M.E. approved electric welded construction, it is built to withstand 100 lb. working pressure or full vacuum. United Welding & Manufacturing Co., a division of Harris Enterprises, Inc., Los Angeles manufacturer of industrial, chemical and food processing equipment, is the designer and fabricator.

The determining factor in the selection in the United Welding vessel was the quick opening safety door feature, an exclusive development of United Welding and Manufacturing Co.

In order to load and unload the vessel rapidly, one entire end of the chamber must be opened, requiring a large door, 12 ft. 6 in. in diameter. Such pressure vessel doors must completely seal the chamber for both pressure and vacuum. Many rubber or chemical retorts employ laborious opening and closing methods. In contrast, this door, called the Harris Quick-Opening Safety Door, opens or closes, sealing or unsealing completely in approximately 35 sec. Harris doors up to 6 ft. in diameter will open in the remarkably fast time of 4 sec., will close in 2 sec.

Press

The Warco Press Division of The Federal Machine and Welder Co., Warren, Ohio, has recently designed and built a 75-ton press capable of producing a great number of stampings accurately and continuously at high speeds. This press is of welded and stress-relieved steel construction with hand-fit square gibbing to assure accurate alignment.

Auxiliary equipment on this press includes a Warco Precision Double Roll Feed designed for high-speed operation and incorporating the following features: All moving parts are designed to keep weight to a minimum consistent with strength and rigidity requirements, which results in greater feeding accuracy. Infinite variation is possible in feed lengths, from zero to maximum. Synchronized scrap shear is provided if required. The height of feed line is easily adjusted. The stock oiler is also a built-in feature.

NET MONTHLY ADVERTISING RATES
Black and White **Effective July 11, 1947**

Space	One Insertion	Three Insertions	Six Insertions	Twelve Insertions
*Full page	$185	$165	$150	$140
Two-thirds page	130	120	110	100
Half Page	105	95	85	80
Quarter Page	60	58	55	50
Eighth Page	40	35	30	28
*Inside Preferred	205	185	170	160

10% Extra for bleed full pages. Color $65 extra per color added
Agency Commission —15%
Cash Discount — 2%, 10 days

Time Counts—
Gas cut and Weld with
Shawinigan Carbide
SHAWINIGAN
SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING, NEW YORK 1, N.Y.

YOUR GUIDE TO BETTER WELDING

HERE is a handy data sheet that can help you get good results in Gas Welding, Arc Welding or Furnace Brazing. It lists the different types of jobs you might want to do and shows which Revere Welding Rod will give best results in each use. This data sheet is free for the asking—write for your copy today.

Revere Welding Rods are among the many copper and copper alloy products made by Revere Copper and Brass Incorporated. As with other Revere products, constant research, modern production equipment, and rigid quality control have made Revere Welding Rods unsurpassed in quality and performance.

Revere Welding Rods include: Revere 456 Low-Fuming Bronze Welding Rod, Revere Bronze 380, Manganese Bronze, Herculoy, Phosphor Bronzes, Brass (Brazing Rod), Silicon Deoxidized Copper and Electrolytic Copper. All come in 100-pound cases or in 25-pound cartons, net weight, and are stocked by Revere Welding Rod Distributors in all parts of the country.

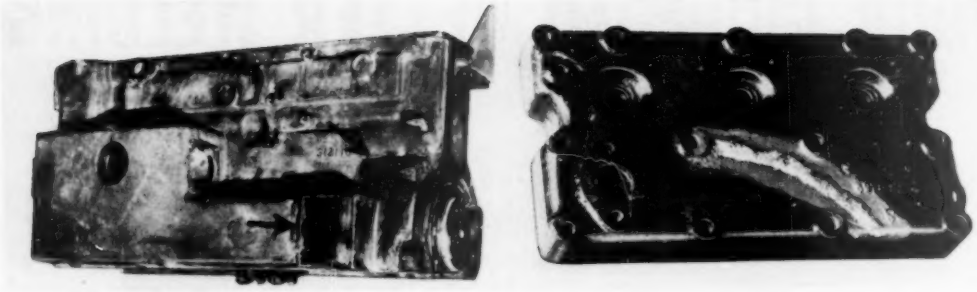
REVERE

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801
230 Park Avenue, New York 17, N.Y.

* * *

Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; New Bedford, Mass.; Rome, N.Y.
Sales Offices in Principal Cities, Distributors Everywhere.



Cracked motor blocks easily repaired

Repairs of Cracked Motor Blocks

Automobile repairmen will welcome the news of a new, low-heat electrode for welding cast-iron motor blocks, which may have cracked during cold weather sieges.

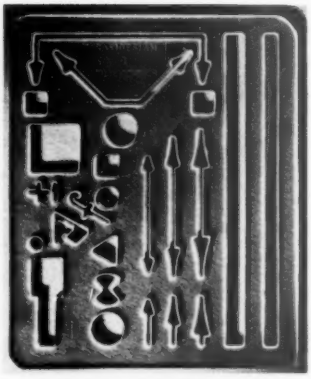
Reports indicate this Frigidare coated Eutectrode 24/49 may be used for on-the-spot repairs *without any preheating or dismantling of equipment*. Cracks, breaks, wear and defective areas are now easily repaired without loss of time. Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N.Y.

Design Template

Rapidesign, Inc., announces the new No. 60 Dimensioner template for use in all phases of drafting.

The new No. 60 Dimensioner template speeds up the callout, dimensioning and lettering of drawings. Makes standard drafting symbols easily, neatly and accurately. An indispensable template where drafting procedure requires uniformity. All symbols and sizes conform to standard drafting room practice.

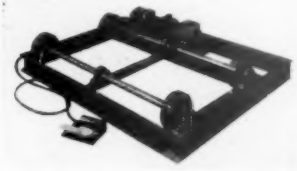
The No. 60 Dimensioner is made of 0.040 super quality cellulose nitrate.



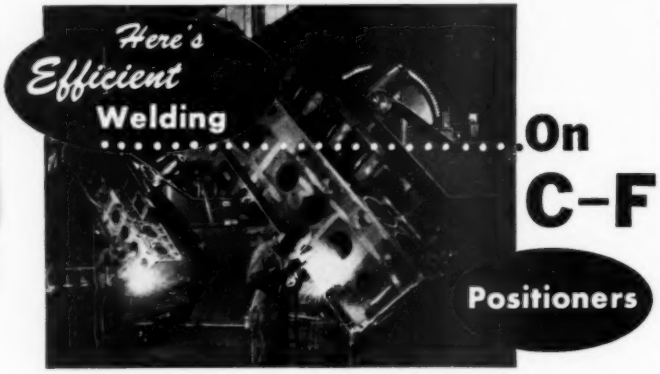
Beveled cutouts of symbols are precision milled to give utmost in accuracy. Actual size 4 x 3¼ in., price $1.00. Write Rapidesign, Inc., P. O. Box 592, Glendale, Calif.

New Unit Type Turning Roll

Illustrated here is the new Model RD-20 unit type turning roll recently placed on the market by the Reed Engineering Co., of Carthage, Mo. This machine is used principally for the rotation of tanks and cylindrical shapes for welding and painting tanks, and also used for flame cutting pipes and cylindrical shapes.



It is equipped with four rubber tired wheels, two of which are driven and two of which act as idlers. Machine is fully adjustable to handle any range of diameters from 3 in. to 6 ft. and any length from 12 in. to 12 ft. It has a capacity of 2000 lb. total weight, and is equipped with a variable speed transmission which gives any range of speeds from 0 up to 120 in. per minute. Antifriction bearings are used throughout and all primary reductions are totally enclosed worm gear type.



When heavy, unwieldy weldments like these diesel crank cases can be quickly swung into any position so that every weld is made downhand —that's efficient welding!

Weldors spend more time welding—do better welding at lower cost when they work with C-F Positioners because these hand or power operated machines reduce positioning time to a minimum. Investigate the cost-saving advantages of C-F Positioners. They pay their way in any company.

Write for Bulletin WP24—an illustrated circular detailing the specific advantages of C-F Positioners

Cullen-Friestedt Co., 1323 Kilbourn Ave., Chicago

CULLEN-FRIESTEDT CO., CHICAGO 23, ILL.

C-F positioned welds mean better, more economical welds

Machine comes complete with motor and foot-operated switch. Over-all dimensions are 60 in. wide x 72 in. long. Shipping weight, 700 lb. At the present time shipments can be made from stock.

Synchro-Matic Flash-Butt Welding Process

The new Thomson Synchro-Matic Flash Welder provides automatic control of flashing and upset with the entire welding sequence precisely synchronized and reduced to a simple, push-button process. The machine is extremely simple to operate, being provided with settings and calibrated scales for upset and flash-off distances and for welding time. Values recommended or known to produce good welds are used to set up the machine and the work is clamped. Thereafter, once the operation is initiated either by pushing a button or stepping on a foot switch, the machine takes over. Flashing takes place during a relatively slow but accurate and smooth acceleration. At the most favorable moment, the upset occurs as an additional acceleration of the moving platen, producing the actual weld.

The advantages of the Synchro-Matic Process are obvious. Anyone can operate the machine since it involves only three simple settings and pushing a button. Weld quality can be duplicated exactly on a production scale. Dimensions of the welded piece can be held to close limits and allowance for flash-off and upset can be held to a minimum.

A Synchro-Matic Flash Welder will not only produce sound welds with ease in mild or alloy steels but because of its uniform precision features will consistently produce good welds in bronzes, brasses and aluminum and magnesium alloys. Combinations normally considered impracticable such as copper-to-copper or copper-to-aluminum can be welded with ease.

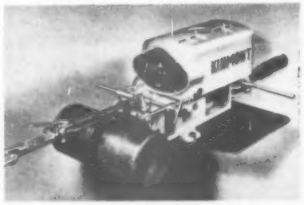
The Synchro-Matic unit is a simple, compact device. Motive force for the movable platen is supplied by an air cylinder controlled by a hydraulic snubber. No elaborate piping, dump valves, solenoids or other complicated elements are involved. Otherwise, Synchro-Matic Flash Welders are conventional in design and are applicable to the entire range of work now handled by conventional flash welders. Any type of clamps—manual, pneumatic or hydraulic—and any standard or special tooling can be mounted on the "table top" platens.

Complete information is available in bulletin form from the manufacturer, Thomson Electric Welder Co., Lynn, Mass.

New Cutting Torch Attachment

A new cutting torch attachment is an important accessory now available for use with the Kinmont Universal Power Unit, manufactured by the Kinmont Mfg. Co., Inc., of Glendale, Calif.

The principal features of this attachment are its provision for easy and fast adjustment of the cutting torch in handling a wide range of pipe sizes, and its ability to maintain a smooth bevel and square cutoff across the end of the pipe.

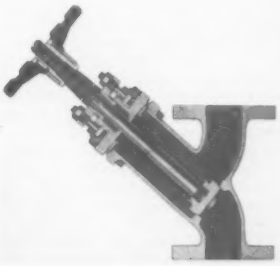


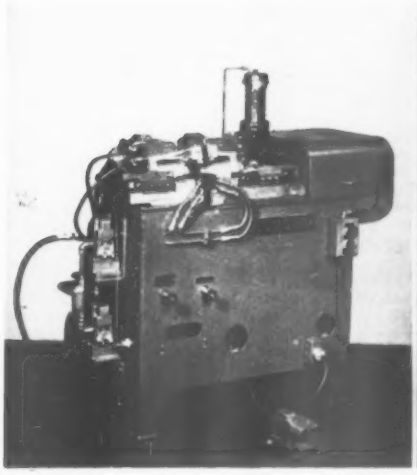
The wide adjustment range of the cutting torch attachment permits its use on any pipe size from 3 up to 36 in. in diameter, and on tanks up to 10 ft. in diameter when turned on a roller rack. The turning speed of the Kinmont Universal Power Unit is controllable while cutting operation is in progress, thus assuring a smoothly finished cut. A foot switch controlling the turning operation leaves the operator's hands free to control the torch and speed adjustments.

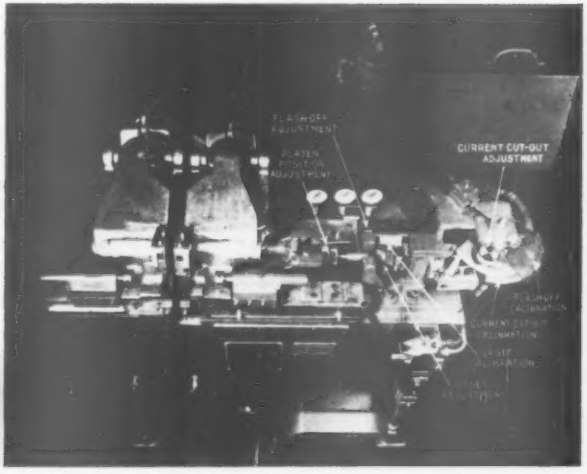
For further details, write to Kinmont Mfg. Co., Inc., 716–718 W. Wilson Ave., Glendale 3, Calif.

Packless Valve

The ever-present problem of human safety, property damage and production losses is a constant concern in plants processing highly corrosive gases or liquids. This problem is particularly important where explosive, poisonous, inflammable or corrosive substances are in process. It is, therefore, welcome news for these industries that Magnilastic Division of Cook Electric Co., Chicago, has developed a standard series of corrosion resistant metal bellows of all-welded construction which seal valve stems against any and all corrosive agents. These bellows-sealed valve stems are designed and adapted to a wide range of valves manufactured by a number of valve manufacturers as a specialized service. Magnilastic does not manufacture valves.







Views of the synchro-matic-flash-butt welder

SECTION ACTIVITIES

Prepared by C. M. O'Leary

To avoid possibility of inaccurate reporting in the write-up of Section Activities in The Welding Journal, no information will be included unless headquarters receives a definite write-up or a report indicating exactly what transpired at a specific meeting. Advance notice of such a meeting cannot be accepted as having actually happened unless accompanied by a signed statement or a report to that effect.

Anthony Wayne

The November 26th meeting of the Anthony Wayne Section held at the Fort Wayne Chamber of Commerce, was informally started with a very appetizing Buffet Dinner at 6:30 P.M. After dinner, the group moved to the auditorium where the Coffee Session Entertainment was presented in the form of a chalk talk by Eugene W. Craig, Editorial Cartoonist of the Fort Wayne *News-Sentinel*.

Next was presented a very educational sound film, produced by General Electric Co., entitled "This Is Resistance Welding," which quite thoroughly and clearly covered the various popular types of resistance welding—projection, spot, seam and flash.

When the film was over, the Chairman, George H. Laws introduced J. R. Wirt of Anderson, Ind., 5th District Vice-President of the A.W.S. Mr. Wirt then introduced the speaker of the evening, George Sieger, President of S-M-S Corp. and President of the AMERICAN WELDING SOCIETY.

Mr. Sieger's talk, which was unusually forceful and spiced with very dramatic and humorous similes and illustrations, was directed along the line of "What Good Do We Get Out of the A.W.S." He emphasized the point that in order to get the most good out of it we should be proud of it and advertise its benefits. Through this organization we get the highest type of engineering knowledge at a nominal fee—one of its best selling points.

He made a strong point between "Button Members" who get no good from the organization and "Active Members" who can't afford to be without it. He strongly advised of avoiding the dangers of cliques forming between manufacturers, suppliers, etc.

Continuing his talk, he went into the Resistance Welding part of it by first emphasizing that Resistance Welding was no more competitive to arc or gas welding than these latter two were to each other. He clearly brought out the importance of pressure, current and time to each other in getting successful results as well as the urgency of constancy in tip dressing.

He had quite a display of various samples of work that could be and is being welded by the resistance welding method, many of which were quite new to the crowd attending. Afterward, a very interesting and educational Question and Answer Period was conducted with great interest evidenced by the entire group.

Approximately 120 attended the meeting, many coming from quite some distance. In view of the inclement weather that evening, this would indicate a great deal of interest in attendance and in talking with Mr. Sieger.

Birmingham

A general discussion on the mechanical and physical properties of nickel, Monel and Inconel was presented by K. M. Spicer in a talk entitled, "Welding of Nickel and High Nickel Alloys," before a meeting of the Birmingham Section on Tuesday evening, January 11th.

Mr. Spicer is a member of the Technical Service Section of the Development and Research Division of The International Nickel Co., Inc., New York.

Bridgeport

The Bridgeport Section's December meeting held on the 11th was highlighted by a gala Christmas Party. To foster better fellowship and acquaintances in the Section, the gathering was completely informal and well attended by 30 members, guests and their wives. A turkey dinner opened the evening at 8:00 P.M. at the Housatonic Lodge, followed by an evening of dancing to the tune of King's Orchestra. The purpose for which this party was held was well accomplished in that when the party was over everyone present was calling each other by their first names. Beer and setups were furnished by the Section. Other refreshments were furnished by the members.

Chattanooga

A general discussion on the mechanical and physical properties of nickel, Monel and Inconel was presented by K. M. Spicer in a talk entitled, "Welding of Nickel and High Nickel Alloys," at a meeting of the Chattanooga Section held on Monday evening, January 10th.

Mr. Spicer is a member of the Technical Service Section of the Development and Research Division of The International Nickel Co., Inc., New York.

The meeting was held at Edgerton's Dutch Manor. Refreshments were served at 6:00 P.M. Dinner at 6:30.

Chicago

Good attendance and enthusiastic discussion of the technical subject of the evening marked the December 17th meeting of the Chicago Section. More than 100 members and guests met at the People's Gas Light and Coke Co. auditorium to hear Walter A. Knocke, welding consultant, Weldkraft, Inc., speak on "Welding of Tool Steels in Tool Dies and Fixtures."

Mr. Knocke showed slides of such welding jobs as repairs to $^1/_{32}$-in. teeth in rolling cutting dies. He mentioned that much of the die welding work is being done for manufacturers of plastic products and die cast parts. The atomic-hydrogen process has been found very useful for welding tool steels, Mr. Knocke observed, because it allows smaller deposits and more favorable heat control. Preheat, postheat and metallurgical data are also essential to consistent results and high-quality work, he advised.

Charles W. Steels, local chairman, presided over the meeting. Announcement was made of the resignation of Richard W. Raney as chairman of the Membership Committee because of his transfer to Youngstown, Ohio. W. C. Henzlik was appointed to take care of publicity for the local section.

The premeeting dinner was held at Burke's Grille and Restaurant. A color movie, "The Grand Canyon in Northern Arizona" and a sport film, "Championship Form," of Olympic track and pool stars in action, were shown before the technical presentation.

Cincinnati

An Inspection Trip and Metal Show were held by the Cincinnati Section on Tuesday, December 14th, at 8:00 P.M. The inspection trip was through the Cincinnati Shaper Co.'s plant, where the building of Large Power Brakes and Squaring Shears is carried on, also live demonstrations of some of the newest developments in the welding industry today. The Nelson Automatic Stud Welder, the Chris-Torch, the Semi-Automatic Hidden Welding by the Manual Lincolnweld, the Linde Power-Cutting and Scarfing Process and the Shield-O-Matic Welding Process by National Cylinder Gas were all seen and demonstrated.

Cleveland

Maison C. Robbins, District Manager of Handy & Harman, addressed the January 12th meeting on the subject "Silver Brazing and Its Application in Industry."

Mr. Robbins, a graduate of Armour Institute, has worked with the Chicago Bridge & Iron Co. and the Steel Sales Corp. of Chicago. He joined Handy & Harman in 1938 and has been in Cleveland since 1946.

"Whence Came the Red Man" was the

subject of the coffee talk by Casimer M. Nikel, minister of the Reorganized Church of Jesus Christ of Latter Day Saints. His talk was based mainly on the archeological findings during the last century. Mr. Nikel has traveled widely in his work as a clergyman and his experiences among the Indians in the Southwest have stimulated his hobby of investigating these archeological findings.

Columbus

The December meeting held on the 11th was very interesting and informative.

Robert W. Bennett of Battelle Memorial Institute was given a cheery send-off to his new position at the American Locomotive Co., in Dunkirk, N. Y. Mr. Bennett was replaced by A. R. Meyer of Battelle as Chairman of the Educational Committee.

Visitors from Dayton and Marion, Ohio, found both the Dinner talk and the Technical talk well worth their long trip.

The Coffee Speaker, Milton Forman, of Battelle, gave some worth-while information on welder qualification. He broke the testing of the welders into five parts: Size and type of electrode; type of joint; position in which work is to be done; thickness of plate; material.

The Technical Speaker, C. B. Voldrich, gave a talk on the welding of heavy aluminum plate as well as the welding of high strength aluminum. Mr. Voldrich also explained the use of various pieces of equipment used to weld the heavy aluminum and aluminum alloys; from the oxyacetylene process to the newest process, "Aircomatic," a gun with continuous rod speed and feed, with argon gas as the shielding element. At the completion of his talk, Mr. Voldrich showed some samples of heavy aluminum welding which received considerable attention.

Detroit

The December 10th meeting featured Patrons Night which is the Annual holiday party sponsored by the Patrons.

On the serious side, an inspiring lecture, "Main Spring" was delivered by Henry Grady Weaver of General Motors Co. Mr. Weaver, who has published a book by the same title, told his audience of 150 why we are the greatest nation and what it is that makes us so great. He drew many references from his book which he calls a grass roots primer of Americanism.

Following his talk several vaudeville acts were enjoyed by those present, and games and refreshments completed the evening. The only welding for the evening was that most important to any society—Welding of Friendships.

Henry Grady Weaver died Jan. 2, 1949.

The Saginaw Valley Division held a Christmas Party on Friday, December 10th, at Rolling Green Golf and Country Club. Cocktail Hour preceded the Dinner which was followed by dancing. A good time was had by all.

Hartford

Regular monthly dinner meeting of the Hartford Section was held on Thursday, December 16th, at the Whitlock Mfg. Co. Cafeteria, Elmwood, Conn. "Practical Aspects of Resistance Welding," was the subject presented by Richard H. Florian, Methods Engineer, Trumbull Electric Mfg. Co., and Frank J. Wallace, Pratt & Whitney Aircraft.

A Resistance Welding film was shown through the courtesy of the General Electric Co.

Indiana

The Indiana Section held a Christmas Program meeting on December 17th at the Warren Hotel, Indianapolis.

Wally Nehrling, radio announcer at Station WIRE, was the dinner speaker.

This being a Christmas Party women and children were present for the dinner and entertainment.

Lehigh Valley

LaMotte Grover, Welding Engineer, Air Reduction Sales Co., was the guest speaker at the monthly meeting of the Lehigh Valley Section held on Monday, January 3rd, at the Hotel Bethlehem, Bethlehem, Pa. C. L. Kreidler, Chairman, presided at the meeting.

Mr. Grover spoke on the "Economics of Welding." He discussed numerous advantages of structural welding, such as the reduction of weight and cost of structural members, greater flexibility and freedom in architectural and structural design, and better appearance because of smoother surfaces and outlines. The talk was illustrated with slides showing various welded buildings and bridges which have been constructed throughout the United States and Canada. An informal discussion period followed the talk.

H. O. Hill, of the Bethlehem Steel Co., gave an interesting after-dinner talk entitled, "A Florida Travelogue." The talk was illustrated with beautiful color slides showing historical and scenic points of interest which he photographed on a recent visit to Florida.

C. L. Kreidler presented Mr. Hill with a gift in behalf of the members of the Lehigh Valley Section as a token of appreciation for services rendered and the recognition brought to the Section while Mr. Hill was serving as President of the A.W.S.

A special committee composed of Q. E. Charlesworth, L. P. Elly and J. R. Fairhurst, was appointed to arrange the Annual Meeting program for May 2nd. The Section hopes that it will have a meeting comparable to previous years, at which times all members and guests attending the affair had a very enjoyable evening.

Mahoning Valley

Monthly meeting was held on October 21st in Youngstown, Ohio. N. E. Wheeler spoke on "Production Welding in the Automotive Trucks Industry."

November meeting was held on the 18th. Robert J. Berlesky spoke on "Repair Welding of Heavy Wall Pressure Vessels."

Michiana

The Michiana Section held a joint meeting with the Notre Dame Section of the American Society for Metals on Wednesday, December 8th, at Notre Dame University, with Dr. R. D. Stout of Lehigh University, speaking on "The Metallurgy of Arc Welding."

He described a series of experiments made by laying beads on a plate of structural steel before and after various heat treatments and checking the properties of the base metal by removing a portion of the bead and testing the plate in bending. The benefits of postheating and preheating were quite obvious, and surprisingly great for a steel that is nominally nonhardenable.

Milwaukee

W. J. Phillips, Director, Casting Development Dept. Steel Founders Society of America, was the speaker at the December 17th meeting held at the Ambassador Hotel.

Mr. Phillips discussed "Weldability of Steel Castings." He divided the carbon steel castings into groups: those readily weldable having a carbon maximum of 0.25% and a manganese maximum of 0.70%; those with 0.30% carbon or over and manganese 1.00% or more which are not readily weldable; and the alloy castings which require preheat.

A discussion of preparation of defects for welding was followed by some precautions to use subsequent to welding.

Mr. Phillips devoted the latter part of his talk to the proper design of steel castings and showed how it is possible in many cases to make a complex casting more economically by combining a number of smaller castings by welding.

The coffee talk was given by Fred W. Steffan, a Milwaukee alderman, who combines artistic talent with his law making. Mr. Steffan drew some caricatures of some of the section officers, past and present, to the general amusement of all.

About thirty-five attended the dinner and a similar number joined the group after dinner.

A stainless steel lectern designed and manufactured by the Milwaukee Road was presented to the Section at the beginning of the meeting. The lectern has the A.W.S. emblem in colors on a plate in the front. A vote of thanks was offered the railroad for this useful piece of equipment.

A Christmas Smoker was held on December 20th at Moser's Cafe. Entertainment, refreshments and door prizes were enjoyed by all.

Nashville

A business meeting was held in the Maxwell House Hotel on December 17th.

The following matters were attended to: The By-Laws amended and accepted providing for the signature of Section Secretary instead of wire-chairman; committees changed to include only members of Section; proposed program of speakers for year 1948–49 as suggested by District No. 3 meeting held December 1st in Birmingham, Ala., was discussed and referred to the Program Committee.

A General Electric film on a.-c. Welding was shown.

just .007 inch thick, this watch spring . . . but

Elgin tacks it with G-E controlled

GETS MORE RIGID, STRONGER CONSTRUCTION

Welding a new alloy Dura Power mainspring at the Elgin National Watch Company, Elgin, Illinois, is one example of the versatility of resistance welding—made possible by General Electric precision control. Mr. George Ensign, director of research, says . . .

"We specified General Electric control on this resistance welding equipment because of its extreme accuracy and all-round dependability. On delicate work such as this, spoilage can be high unless the welder control works perfectly. Thanks to G-E control, work is easy, accurate, and production is high."

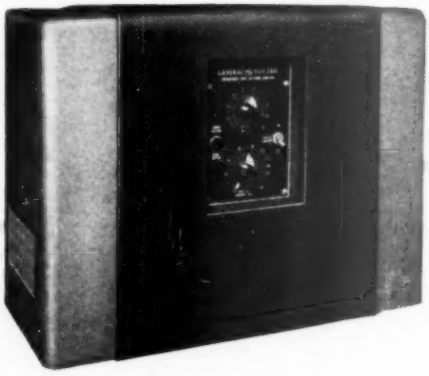
G-E CONTROL USED EVERYWHERE

Many other manufacturers have made similar comments—manufacturers of such widely diversified equipment as car bodies, fuel tanks, refrigerators, kitchen utensils—hundreds of articles in everyday use.

G-E precision control can be used with almost every type of resistance welder—for spot, seam, and projection welds—for any size welder. Fill in and send us the coupon for information on our welding control.

HAVE YOU SEEN "THIS IS RESISTANCE WELDING"?

General Electric's More Power to America, full-color, sound movie on resistance welding processes is packed with ideas for the better use of this manufacturing process. Production men, engineers, designers, and welder operators will benefit—manufacturing problems decrease. Arrange for a free showing with your utility, resistance welder manufacturer, or the nearest G-E office. And remember—specify General Electric control when next you order a welder.



G-E Thyratron spot-welding control panel for bench-type welder

Spot welding a new alloy mainspring at Elgin.

BETTER WELDS FASTER with General Electric

Apparatus Dept., Sec. D 645-47
General Electric Company
Schenectady 5, N. Y.

Please send me the following bulletins:

- ☐ The Importance of Control, GEA-4571
- ☐ Thyratron Welding Control, GEA-4175A
- ☐ Synchronous Control for Spot and Projection Welding, GEA-4699
- ☐ Nonsynchronous Control for Spot and Projection Welding, GEA-4726

Name.....

Company.....

Address.....

City..... State.....

GENERAL ELECTRIC

New Jersey

"The Inert-Gas-Shielded Arc-Welding Process" was the subject of a series of talks presented at the December 21st meeting. The wide interest in this subject was shown by the nature of the discussions following the talks.

The speakers were Bernard J. Blickman of S. Blickman, Inc., who discussed stainless steel welding using the inert-gas process.

J. Imperati, Welding Engineer for the American Brass Co., discussed the welding of copper-base alloys.

O. H. Kuhlke, Welding Engineer in Charge of Welding Research for the General American Transportation Co., discussed aluminum welding using the subject process.

Robert Wilson, of The International Nickel Co., served as moderator.

Mr. Blickman outlined some of the features of the inert-gas welding process for the welding of stainless steel. The ductility of the weld metal is excellent which permits forming the parts after welding.

During Mr. Imperati's talk he brought out the fact that the inert arc is of particular advantage in welding the copper silicon group, including Everdur, Hercoloy, etc.

Mr. Kuhlke described the application of the inert arc welding process as applied to the fabrication of aluminum structures. In the welding of aluminum tank cars his company has found this process to be more satisfactory than the metallic arc, carbon arc, oxyhydrogen and similar processes.

New York

The December meeting held on the 8th in the Engineering Societies Bldg. was a symposium on "Methods of Inspection of Welds" instead of the usual type of program. Alexander Gobus, of Sam Tour & Co., was Moderator for the meeting.

W. B. Bunn, M. W. Kellogg Co., N. J., spoke on "Radiography in Weld Inspection"; H. Migel, Magnaflux Corp., New York City, spoke on "The Application of Magnaflux to Welds"; and J. C. Smack, Sperry Products, Inc., Danbury, Conn., spoke on "Ultrasonic Inspection of Welds." All three speakers supplemented their talks with slides on which they made running comments.

Mr. Bunn described nondestructive tests of welds made with X-ray machines and radium. He explained briefly how each method is used and where each is most effective. Mr. Bunn also had several X-ray films of welds which he showed at the end of the meeting.

Mr. Migel explained the Magnaflux method of making nondestructive tests on welds. In his slides he showed some of the equipment that is needed and briefly described how the tests are made. He stressed the fact that Magnaflux testing is most useful when you are looking for cracks or defects on or near the surface.

Mr. Smack described the principles and theories of ultrasonic weld inspection and also showed slides of the equipment used. He explained that no one of these three nondestructive tests for welds are good under all conditions. The method used depends upon what information is needed and the conditions under which the job is being done. At the end of the meeting, Mr. Smack demonstrated a portable machine for ultrasonic inspection. This machine can be easily carried by two men.

Each paper took about 20 minutes for presentation and there was a short discussion period after each one. Arrangements for the meeting were in charge of H. R. Clauser, Assoc. Editor of Materials and Methods.

Northwest

An afternoon plant tour of the Minneapolis-Moline Power Implement Co., Como Plant, took place on Tuesday, December 14th. Dinner at 6:30 was in the Lodge Room, Covered Wagon.

Elmer Hixson, Welding Engineer, Minneapolis-Moline Power Implement Co., spoke at the evening meeting on the subject "Welded Design of Farm Equipment."

January 11th steak dinner meeting was held in the Lodge Room of the Covered Wagon, Minneapolis. Highlight of the evening was an address by T. Embury Jones of the Precision Welder and Machine Co., who discussed "New Developments in Resistance Welding." A motion picture entitled "This Is Resistance Welding" was also shown.

Ted Kenny of The Kenny Boiler Co. was the host of the Happy Half Hour from 6:00 to 6:30.

Philadelphia

The regular monthly dinner meeting of the Philadelphia Section was held on December 20th in the Engineers Club. George Kelso, Houdry Corp., Philadelphia, was the coffee speaker. Mr. Kelso presented an excellent talk on "Russia—What I Saw" which consisted of his personal experiences in Russia during 1945 and 1946.

Technical speaker was John C. Smack, Sales Engineer, Sperry Products, Inc., Danbury, Conn., whose subject was "Nondestructive Testing of Welds." Mr. Smack's paper dealt with the ultrasonic testing as one method of nondestructive testing. Use of the Reflectroscope was demonstrated at the end of the talk.

Puget Sound

The October 13th meeting was in the nature of a membership meeting making arrangements for a membership drive.

After the meeting, about thirty members of the Section made a visit and complete tour through Kenworth Motor Factory, where they saw many special heavy duty trucks on the production line; a great many of them are designed for heavy hauling in the oil fields of Arabia.

The regular November meeting was held on the 10th at the Engineers Club, Seattle, Wash.

Mr. Morley of the Morley Magnesium Foundries, Inc., gave a good talk on the casting and fabrication of magnesium. The talk and discussion following were of very great interest to all the members present inasmuch as magnesium is rapidly gaining many uses in industry. A number of samples of cast magnesium were on hand for inspection by the group, which created considerable interest.

A very excellent moving picture depicting the manufacturing processes of magnesium was shown.

Rochester

Monthly meeting of the Rochester Section was held on Monday, December 20th, in the Engineering Bldg., University of Rochester, River Campus. Cafeteria style dinner preceded the meeting.

A movie, "The Legend of Useppa," was shown.

Feature of the meeting was the semi-automatic welding device shown by The Lincoln Electric Co. This equipment operates under the submerged arc principle. The wire and flux feed is automatic but the guiding is done by hand.

An educational program of the Rochester Section consisting of a series of six meetings on the subject "The Relation of Design to Arc Welding Procedures" was introduced the week of January 9th. The remainder of the meetings are as follows: February 5th, "Joint Selection"; March 5th, "Electrode Selection"; April 2nd, "Procedures"; April 30th, "Selection of Material"; May 28th, "Proper Use of Material."

St. Louis

A joint meeting of the St. Louis Section of the A.W.S. and the St. Louis Chapter No. 17, American Society of Tool Engineers, was held on Thursday, January 6th, at the Engineers Club. Patrick S. Doyen, Field Engineer, Welding Equipment and Supply Co., Detroit, was the speaker. Mr. Doyen is well versed in the specialized phase of welding tools and dies.

The St. Louis Section held a Smoker on Friday, December 10th, at Belvedere Joe's. Free beer and sandwiches were provided. A good time was had by all.

Toledo

The Toledo Section opened its 1948–49 season with a plant trip through the National Supply Co., Toledo, Ohio, producers of Oil Well Equipment, on Wednesday, September 8th.

There were 41 in the group, who found the trip exceedingly interesting, not only from a welding standpoint, but also because of the unusual equipment for this locality, the method of material handling and the modern plant facilities.

The next regular meeting, comprising an audience of 27, was held on Wednesday, October 13th, in the Commodore Perry Hotel. A. H. Homrighaus, Jr., arranged through the courtesy of Lincoln Electric Co., the showing of the 15-min. film, "Machine Design for Arc Welding."

Following this the speaker, Knowles B. Smith, Vice-President and General Manager of the Dix Engineering Co., Inc., Detroit, talked on "Metal Spray and Metallizing." With the aid of slides he first gave the history of the spray gun development. He then treated the different applications where metal spraying

FOR SHIELDED ARC
AUTOMATIC WELDING

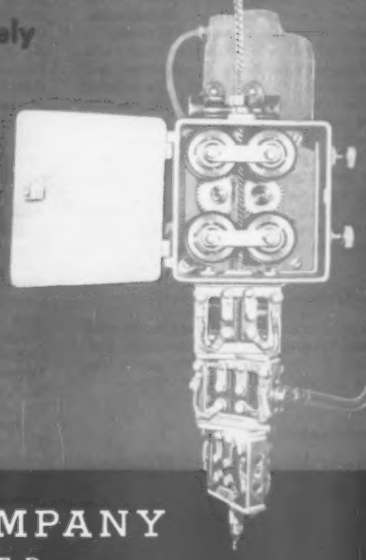
FOR BUILDING UP
HARD SURFACING
with all standard makes of Automatic Arc-Welding heads

Perfect Metal! Weld Smooth as Silk! Fast! No melt to put down or recover!

Mild steel grades, hard-surfacing grades, stainless steel grades. Thickness of overlay can be accurately controlled with minimum machining.

Our field covers the jobs that other automatic-welding methods cannot handle.

RACO Composite Type A does a beautiful job on large or small tanks, pipe, girders, refrigerator compressor units, flexible couplings, pistons, piston rods, rolls, large or small shafts, plungers, locomotive wheel centers, brake-drums, crusher parts, tractor rollers, mine-car wheels, trunnions, etc.



REID-AVERY COMPANY
INCORPORATED
DUNDALK • BALTIMORE 22 • MARYLAND
SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

may be used to advantage and the methods employed in obtaining a good bond between the spray and parent metal. V. R. Smith, Field Engineer for the Metallizing Engineering Co., Inc., who was in the audience, elaborated on some points during the talk and during the question period.

On Wednesday, November 10th, in the Commodore Perry Hotel there was staged a very unusual meeting. It was unusually good from more than one point of view. In the audience were such out-of-town notables as Ray Stitt, Tom Crawford, W. H. Morris, Robert Bennewitz, John Headapohl, all from Detroit; L. G. Pickhaver from Chicago, J. N. Black from Cleveland and others.

Mr. Stitt, Chairman of the Detroit Section, brought greetings and good wishes from George N. Sieger, President of the A.W.S. He also gave a short talk on program arrangements between Toledo, Detroit and affiliated sections.

The main discourse was in the form of a panel meeting with a topic of "Inert Arc Welding" and was covered by three different speakers. There were 40 very attentive listeners who took in this new and interesting subject.

R. F. Wyer, Application Engineer, of General Electric Co., with the aid of slides covered the equipment in general use today for this type of welding.

H. T. Herbst, Manager, Heliarc Division Lab., of The Linde Air Products Co., explained the different applications. He made use of a color film to show the peculiarities of the arc and slides for details of applications.

The third panel member, E. H. Lee, Regional Manager, Detroit Office of the Federal Communications Commission, pointed out that it is very important to hold electrical interference to vital radio sending and receiving of airplanes and ocean boats to a minimum. He pointed out that shielding of high-frequency equipment will accomplish a great deal in this respect.

During a lively three-quarter hour question period all panel members answered many specialized queries.

The Toledo Section changed its regular monthly meeting date from the second Tuesday to the second Wednesday.

Tri-State

December meeting was held on the 13th in the Vendome Hotel, Evansville, Ind. Russell F. Strate of Air Reduction Co. spoke on "Arc Welding Electrodes."

Washington

Annual joint meeting of the Washington Section of the AMERICAN WELDING SOCIETY and the Washington Chapter of the American Society for Metals was held on Friday, December 17th. Dinner at O'Donnell's Restaurant preceded the meeting held in the Pepco Auditorium.

Dr. Samuel L. Hoyt, Technical Adviser at Battelle Memorial Institute, was the speaker. His subject was the "Principles of Behavior of Steel in Large Structures." Dr. Hoyt contrasted the structural performance in large structures with the performance of the steel in laboratory specimens.

Western Massachusetts

The December meeting of this Section was held on the 14th at Blake's Restaurant, Springfield, Mass.

Paul Moffke, who is well known in this district for his remarkable skill at sleight of hand, entertained both during and after dinner.

F. W. Sehl, chemical engineer for The Aetna Casualty and Surety Co., put on a remarkable demonstration of flash fires and explosions. Mr. Sehl is a well-known authority on this subject and a very competent speaker.

Western New York

A joint meeting with the Niagara Frontier Chapter, American Society of Safety Engineers, was held at the Hotel Touraine, Buffalo, N. Y., on Dec. 16, 1948. One hundred thirty-five members and guests of both participating societies were present for a turkey dinner and the usual social hour preceding the technical session. An officer of the Technical Societies Council of the Niagara Frontier was present as the coffee speaker and outlined the plans and purposes of the organization. The Council is now attempting to encourage the placement of qualified engineers in the many varied positions of public responsibility, especially within New York State, which are in need of expert engineering advice.

An additional 50 to 75 members and guests were present to hear William W. Reddie, Asst. Mgr., Arc Welding Dept., Westinghouse Electric Corp., Buffalo, N. Y., present the main topic, "Safe Practice in Arc Welding." He made it plain that arc welding was essentially not a hazardous process and that accident data do not indicate it to be any different than other occupations. He, however, emphasized that there were many details connected with the operation of both small and large installations that must be recognized and adhered to if accidents were to be prevented. Many of these details were fully described.

R. S. Inglis, Superintendent, Quality Control and Inspection Division, General Electric, Philadelphia, will present the main topic at a joint meeting with the Niagara Frontier Society of Industrial Engineers on February 18th, at the Hotel Touraine, Buffalo, N. Y. His subject will be "Quality Control Methods Applied to Resistance Welding."

Meetings for the remainder of the season are as follows:

March 24th—Joint Meeting, American Society of Civil Engineers and American Institute of Architects. Subject: "Structural Design for Welded Fabrication."

April 21st—Joint Meeting, American Foundrymen's Association. Subject: "Welding and Repair of Castings."

May 19th—Joint Meeting, American Institute of Electrical Engineers. Subject: "Electrical Energy in Welding." Speaker: Mario Sciaky.

June 16th—Annual Party and Installation of Officers.

Wichita

A joint meeting with the American Chemical Society was held on December 9th at the Central Intermediate School Auditorium. Dr. Farrington Daniels, professor of physical chemistry at the University of Wisconsin, and an internationally known atomic scientist, discussed the possibilities of using atomic energy in the future to supplement our temporary coal and oil supply. The facts of atomic fission were explained together with a description of the problems and limitations of atomic power. Dr. Daniels also discussed what is currently known concerning the use of sunlight to obtain increasing amounts of fuel and food in the future.

Worcester

The following are the meetings for the remainder of the season of the Worcester Section.

February 28th—"Job Shop Welding," Jamieson Moore, Union Bag & Paper Co. Movie: "No Keener Blade."

March 28th—"Structural Welding."

April 25th—Annual Meeting.

A meeting of the Officers and Directors of the Worcester Section was held on September 9th in the Welding Engineer's Office of the Pullman Standard Car Mfg. Co.

Regular monthly meeting was held on September 27th at Reynold's Red Roof. E. B. Lutes of Arc Rods, Inc., presented an excellent address on "The Characteristics of Electric Arc-Welding Rods." A movie, "3000 Lb. per Sq. Inch," was shown. Both the talk and the movie were very well received.

October 25th meeting was also held at Reynold's Red Roof. Roger Metzler, of Handy and Harman, was the speaker. His subject "Designing for Silver Alloy Brazing" was accompanied by a film, entitled "Silver Brazing."

York-Central Pa.

George E. Bellow, Technical Sales Engineer, Air Reduction Sales Co., New York, was the speaker at the January 5th meeting held in the Engineers Bldg., York, Pa. Mr. Bellow's subject, "Flux Injection Cutting of Alloy Steel," was supplemented with the showing of a technicolor movie of the process.

"Production of Calcium Carbide and Acetylene" was the subject of the December 1st meeting. Speaker was Albert McMillan, Shawinigan Products Corp.

Canadian Welding Society

Third meeting of the 1948–49 season of the Montreal Chapter was held on Monday, December 20th. This was a "Stump the Experts" Night with L. Payne, Canadian Liquid Air Co. Ltd., as Master of Ceremonies. Judges were G. Cape, Dominion Bridge Co. Ltd., P. Paquin, Canadian Liquid Air Co. Ltd. and the Experts, G. Layt, Steel Co. of Canada Ltd., G. Hahn, Canadian Vickers Ltd., W. W. McCullough, Northern Steel Industries Ltd., F. Thomas, Canada Car &

Foundry Co. Ltd., P. St. Pierre, Canadian General Electric Co. Ltd.

Fourth meeting of the 1948–49 season of the Niagara District Chapter was held on Wednesday, January 5th, at Atlas Steel Auditorium, Welland. "What Is Welding Engineering?" was the subject presented by S. A. Greenberg, Technical Secretary of the AMERICAN WELDING SOCIETY.

Fourth meeting of the 1948–49 series of the Kitchener-Waterloo Chapter was held on Wednesday, January 5th at K-W Y.M.C.A. Auditorium. This was a Local Boy's Night. Master of Ceremonies was A. E. Ellis, Superintendent, North Works, Babcock-Wilcox and Goldie-McCullock Limited, Galt. Experts were: General Arc Welding—N. T. Perrin, Welding Equipment & Supplies Co., Kitchener; General Gas Welding—A. A. Verch, Waterloo Spring Co. Ltd., Kitchener; Hard Surfacing—Prof. E. G. Webb, Dept. of Agricultural Engineering, O.A.C. Guelph; Induction Welding—Bruce Brobst, Kralinator Products Ltd., Preston; Light Gage Welding—K. W. Lymburner, Beatty Bros. Ltd., Fergus.; Stainless Steel—Prof. J. R. Scott, Dept. of Agricultural Engrg., O.A.C., Guelph.

Meeting Day of the Toronto Chapter was Monday, January 10th. Dinner and shop tour of the J. Inglis Plant, Toronto, was the order of the day.

LIST OF NEW MEMBERS

December 1 to December 31, 1948

ANTHONY WAYNE

Alley, Robert (B)
Chiger, Harry G. (C)
Foster, Donald Richard (C)
Mansfield, Glenn H. (B)
Peiffer, Arnold M. (B)
Ritenour, Hugh B. (B)

BIRMINGHAM

Ellithorpe, Dean A. (B)
Given, William M., Jr. (B)
Johnson, J. B. (B)

BOSTON

Durocher, Lionel E. (B)
Koopman, Millard P. (B)
Koziarski, Jozef (B)

BRIDGEPORT

Fitting, H. T. (C)
Murto, Lauri John (C)

CHATTANOOGA

Ingram, Fain W. (C)

CHICAGO

Evans, Robert L. (C)

CLEVELAND

Greene, Ralph (C)
Hunter, Clarence G. (C)
Milligan, James Graham (C)
Sprouse, Donald H. (C)
Weed, Daniel H. (C)

COLUMBUS

Hanes, Walter W. (C)

DAYTON

Weihrauch, Emmett M. (C)

DETROIT

Banyas, Alex T. (B)
Duffin, James B. (B)
Kelsey, Allen W. (B)
Kramer, William P. (C)
La Forest, Edward H. (C)
Ledbetter, E. C. (B)
McIntosh, Donald J. (B)
Morse, Wallace R. (B)
Tebben, John D. (B)
Vanzo, Joseph (B)
Whalen, Floyd (B)

INDIANA

Cooper, John E. (B)
Hight, George R. (B)
Stout, F. D. (B)
Trussel, Jack B. (B)
White, Alton R. (B)

LEHIGH VALLEY

Bresky, Peter W. (C)
Cronin, A. R. (C)
Eichert, William A. (C)
Folmsbee, C. H. (C)
Harding, William E. (B)
Kepner, Ben S. (C)
Leisenring, Albert Conrad (C)
Vorbleski, Walter F. (C)

LOS ANGELES

Drahos, Franklin R. (B)

MARYLAND

Snyder, Charles L. (C)

NEW JERSEY

Henry, Dean (B)
Lawson, Alexander E., Jr. (D)
Sturges, H. D. (B)
Walsh, Henry J. (C)

NEW YORK

Allen, John L. (C)
Bogenrief, William R. (C)
Casey, G. Fraser (C)
Chambers, Ernest A. (C)
Crumish, William (C)
Dietrich, William H. (C)
Eagan, Joseph (C)
Eccarius, H. J. (C)
Foley, John L. (C)
Fulton, Robert E. (C)
Harrington, Mahlon J. (C)
Krankewitz, William (C)
Limoli, Jule E. (C)
Narter, Albert N. (C)
Pernick, I. G. (C)
Quinn, William T. (C)
Shea, Patrick J. (C)
Stianson, Stanley G. (C)
Van Riper, Vincent (C)
Watson, Robert (C)
Yaroslawski, Peter (C)

NORTHERN NEW YORK

Iverson, Einar F. (D)

NORTHWEST

Bohmbach, Fred (C)
Hoppenstedt, J. J. (C)
Larson, Fredolph (B)
McEwen, LeRoy (C)

NORTHWESTERN PA.

Lawrence, Raymond H. (C)

OKLAHOMA CITY

Hare, Milam P. (C)
Hopkins, W. W. (C)
Jones, Carl E. (D)
Myers, Phil L., Jr. (D)

PEORIA

Rehm, G. A. (B)

PHILADELPHIA

Bissout, Herbert A. (B)
Durst, Robert M. (C)
Hepner, Charles F. (C)
Newman, Edward C. (C)
Plant, Franklin, Jr. (C)
Quaid, James A. (B)
Skutta, Frank R. (C)

PITTSBURGH

Colarossi, Lawrence A. (C)

PORTLAND

Ofner, Frank (B)

PUGET SOUND

Adams, C. K. (C)
Green, Samuel A. (C)
Lascelle, Keith L. (C)
Palmer, William F. (B)
Schraw, Harold Martin (C)
Tearjen, Jack A. (C)
Tennery, Richard E. (C)
Whitlock, Victor J. (B)

ROCHESTER

Howe, John E. (C)
Zachman, Clayton C. (C)

ST. LOUIS

Brauss, Norman W. (C)
Fausek, Al. V., Jr. (D)

SOUTH TEXAS

Crick, H. F. (C)
McKissick, J. A. (C)

TRI-STATE

Jarboe, Thomas B. (B)
Kohlmeyer, Robert C. (B)
Niekamp, Webb (C)

WASHINGTON

Pellini, William S. (C)
Taylor, Reginald W. (C)
Zuidema, Charles M. (C)

WESTERN MICH.

Barton, Garald A. (B)
Bosch, Albert W. (C)
Strawbridge, Theodore A. (B)
Warden, Paul Z. (B)

WESTERN NEW YORK

Lyons, Harry G. (C)

WORCESTER

Bell, George C. (C)

NOT IN SECTIONS

Briones, Herman G. (B)
Chasin, Philip (D)
Cheng, C. F. (B)
Diethelm, Jaques (C)
Fraser, Graeme (C)
Heyn, G. H. (B)
Jackson, Henry Ervin (B)
Jacobsen, L. M. (C)
Kulperger, John (C)
DeMagalhaeb, Carlos Geralde (B)
Tait, Andrew E. (C)
Upton, Luther J., Jr. (B)

Members Reclassified

During month of December

DETROIT

Conway, George F. (C to B)

PHILADELPHIA

Ramsay, William L. (C to B)

ST. LOUIS

Pitts, George O. (C to B)

abstracts of CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,454,338—Apparatus for Welding—Albert F. Pityo, Clifton, and Harry E. Butterfield, Jr., Maplewood, N. J.

In this patent, the welding apparatus includes an electrode in the form of a resilient elongated blade and a handle carrying the resilient electrode blade and extending longitidinally thereof and overlapping same. A switch for the welding circuit is mounted upon the handle and has a moving part arranged to be shifted by flexing of the resilient elongated electrode, and an adjustable element is mounted upon the handle and engages the resilient electrode blade to regulate the tension set up thereby.

2,454,617—Welding Electrode Holder—Eric Siemers, Kalamazoo, Mich., assignor by mesne assignments to Lacey—Webber Co., Kalamazoo, Mich., a corporation of Michigan.

The electrode holder of this patent includes a substantially hollow body member having a metal plunger located within the body member and adapted to reciprocate therein. The plunger and body member have cooperating openings for positioning an electrode thereby. One of the features of the holder is that an insulating cover is secured to the body member and a separate insulating cover secured to the plunger.

2,454,948—Electric Resistance Seam Welding Apparatus—Clifford S. Seltzer, Warren, Ohio, assignor to The Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

In Seltzer's welding apparatus, a welding horn of current conductive material is positioned in the path of articles such as tubular can bodies which are moved in succession onto the welding horn. A welding wheel is journaled in one portion of the horn for rolling contact with the inner surface of the article being welded and an external welding wheel electrode is provided for applying welding pressure to the can or other article from the outer surface thereof. Separate means are provided for rotating the inner electrode wheel and other means rotate the external electrode wheel.

2,455,057—Electric Welding Apparatus—Kenneth V. Hart, Cleveland, Ohio.

Hart's welding apparatus includes an article pressing die and a multipart tube clamping die. Transformer secondary means are connected in parallel to the pressing die at a plurality of spaced places and also connect to each of the parts of the clamping die.

2,455,108—Electrode Holder—Hector Beauregarde, Utica, Mich.

The electrode holder disclosed in this patent includes a pair of pivoted members one of which positions a copper block thereon with a surface having a series of grooves at various angles to the longitudinal axis of the block and the other of the members has a terminal portion substantially parallel with the surface of the block when in contact therewith whereby an electrode can be clamped between the surface of the grooved block and the other pivoted member of the holder.

2,455,244—Stud for Welding—Charles S. Evans, Atherton, Calif., assignor by mesne assignments to Morton Gregory Corp., a corporation of Michigan.

Evans' welding stud includes a rod which has on the welding end thereof a plurality of tabs that converge together to provide a chamber. Welding flux is positioned in such chamber.

2,455,325—Heavy-Duty Electrode Holder—Martin Wells, Los Angeles Calif.

In this patented electrode holder, the positioning handle has an opening defined by metal wall means and a screw member projects forwardly from such opening in the handle. A metal body engages with the screw member and has rod clamping means thereon actuated by the turning of the screw member in the threads formed in the opening in the holder. Metal connecting parts extend from the metal body into the opening in the handle and other means engage same to apply force to such metal connecting parts to force same into pressure engagement with the metal wall means defining the opening in the handle. Such pressure is set up when the screw member actuates the rod clamping means of the holder.

2,455,346—Welder for Mesh Fabrics—Charles C. Wickwire, Cortland, N. Y., assignor to Wickwire Bros., Inc., Cortland, N. Y., a corporation of New York.

This patent covers a special type of a fabricwelding machine for welding the warp and weft wires of a wire fabric together.

2,455,441—Arc Welding Within Hydrocarbon Oil—Paul Peillon, Cairo, Egypt, Assignor to Salvage & Marine Co. of Egypt S. A. E., Cairo, Egypt, an Egyptian Company.

An arc-welding process is covered in this patent and relates to a process wherein the metal pieces to be welded are immersed in a hydro-carbon oil with the pieces in proper relative position. An electrode is provided which has a flux covering that is rendered impervious to the hydro-carbon oil by impregnation with a protective compound. The weld is effected by striking an arc between the electrode and the work to deposit molten metal from the arc on the pieces to be welded and form a seam along a joint being formed therebetween.

2,455,526—Welding Apparatus—David Sciaky, Chicago, Ill., Assignor to Welding Research, Inc., Chicago, Ill., a corporation of Illinois

The patented welding apparatus in this instance includes a pair of electrodes for holding work pieces to be welded and a movable slide supporting one electrode and mounting same for reciprocating movement toward and from the other electrode. A tapered cam member is provided and is adapted to be reciprocated in a direction normal to the direction of movement of the slide for moving the slide. A special pressure cylinder is included in the apparatus for controlling the movement of the cam member.

2,455,560—Method of Arranging and Brazing Superposed Commutator Leads—Carroll F. Cobb, Silverton, Ohio, and John R. Guenther, Chicago, Ill., assignors to Allis-Chalmers Mfg. Co., Milwaukee, Wis., a corporation of Delaware

A special process is disclosed in this patent for brazing commutator leads to a commutator.

2,455,564—Spot Welding Apparatus—William H. Dailey, Jr., Library, Pa., assignor to Carnegie-Illinois Steel Corp., a corporation of New Jersey

Dailey's welding apparatus is particularly suited for joining ends of metal strips together and includes a support having a

flat surface along which the strips may pass and a transverse frame bridging the support and being mounted thereon. A clamping device is carried by the frame and is adapted to engage and hold strips on the support when desired. A welding carriage is carried by the frame for transverse adjustment thereon and it has a vertically movable welding device which can be engaged with strips on the support.

2,456,121—Flux Coating for Welding Rods—Walter Goerg, North Bergen, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York

This flux coating for a weld rod is made from boric acid in relatively large quantities and smaller quantities of borax, sodium silicate, alkali metal bichromate and sodium alginate.

2,456,593—Silver Brazing Alloy Containing Indium—Joseph F. Polak, Newark, N. J., assignor to Monroe Sherman, New York, N. Y.

The alloy covered by this patent includes a relatively large quantity of silver, and smaller quantities of copper, zinc, cadmium and indium with no other metals being present in the alloy.

2,456,594—Brazing Alloy—Joseph F. Polak, Newark, N. J., assignor to Monroe Sherman, New York, N. Y.

This brazing alloy comprises a relatively large quantity of cadmium and smaller quantities of silver and zinc with a small quantity of copper also being present in the alloy.

2,456,609—Welding Electrodes—William Andrews, Gateshead-on-Tyne, England, Assignor to Metal & Thermit Corp., New York, N. Y.

Andrews' patent particularly relates to a flux coated nonferrous welding rod for welding metal such as aluminum, copper, nickel, alloys of such metals and nickel-chromium stainless steel. One particular feature of the electrode is that the flux coating is made from a mixture of the halides of lithium, sodium, potassium, and magnesium and a paste made from water, sodium chloride and a synthetic colloidal cryolite.

2,456,664—Split Chuck for Electric Welding Guns—William P. Yurgensen, Sharon Hill, Pa.

The chuck covered by the patent includes a body which is longitudinally slotted at one end to provide a plurality of longitudinally extending portions which are flexible with respect to each other in a transverse direction. A plurality of ears are detachably secured to such body portions at the slotted end of the body.

2,456,933—Brazing Alloy—Wasil W. Dyrkacz, Schenectady, N. Y., assignor to General Electric Co., a corporation of New York

The brazing alloy of the patent is suited for use in brazing copper to fernico alloys. The brazing alloy consists of 86 parts silver, 13 parts copper and one part phosphorus.

Employment Service Bulletin

Services Available

A-566. Welding Supervisor. American, now residing in Europe, available March 15th. Experienced in Boiler, Power Piping and Refinery work. Write to Basil Osman, care Worldwide Contractors Clearance Corp., 50 E. 42nd St., New York 17, N. Y.

A-567. Welding Engineer. Graduate M.E. Age 34. Married. Thoroughly experienced in practical welding on all metals and alloys. Able to work closely with both shop and engineering departments. Interested in developing improved methods. Twelve years' experience in welded fabrication in the following fields: Chemical Plant Equipment, Dairy and Food Equipment, Heavy Machinery and Refinery Equipment.

Position Vacant

V-232. Wanted—Sales Representatives by leading manufacturer of Resistance Welding Machines for following territories: Minnesota; Indiana (except northwestern counties); Metropolitan New York; New England; Southeastern U.S.; and Texas. Liberal commissions. In applying give full details of experience and accounts now represented. Write Box V-232, c/o The Welding Journal.

Current Welding Literature

(*Continued from page 140*)

Electric Welding Machines, Resistance. 48,000 Welds an Hour. Iron Age, vol. 162, no. 23 (Dec. 2, 1948), p. 113.

Jigs and Fixtures. Welding Jig Guarantees Accurate Cabinet Making. Sheet Metal Worker, vol. 39, no. 9 (Sept. 1948), p. 44.

Light Metals. Causes of Scatter in Tensile Strength of Magnesium-Manganese Alloy Welds, J. Pendleton. Sheet Metal Industries, vol. 25, no. 259 (Nov. 1948), pp. 2274, 2276.

Materials Handling, Automobile Plants. Revolutionary Automation at Ford Operates with Iron Hand, J. Geschelin. Automotive Industries, vol. 99, no. 10 (Nov. 15, 1948), pp. 24–27, 70, 72.

Metallurgy Research. Cooperative Research Activities. Metallurgia, vol. 38, no. 227 (Sept. 1948), pp. 267–285.

Metals, Hard Facing. Use of Hard Surfacing, H. P. Kerr. New Zealand Eng., vol. 3, no. 9 (Sept. 10, 1948), pp. 893–895.

Molybdenum. Machining High Purity Molybdenum, J. Gelok. Iron Age, vol. 162, no. 24 (Dec. 9, 1948), pp. 106–110, no. 25 (Dec. 16), pp. 86–89.

Natural Gas Pipe Lines. Gas Pipeline in Argentina. Petroleum (Lond.), vol. 11, no. 11 (Nov. 1948), pp. 254, 266.

Natural Gas Pipe Lines, Explosion Hazards. Nitrogen Purging of Pipelines and Repairs Through Controlled Fire, G. Chabre and J. A. Millen. Gas, vol. 24, no. 9 (Sept. 1948), pp. 55–59.

Natural Gas Pipe Lines. Field Experience on Gamma Ray Inspection of Welds in High Pressure Pipe Line, A. B. Lauderbaugh and S. A. Brosky. Gas Age, vol. 102, no. 12 (Dec. 9, 1948), pp. 25–27.

Nonferrous Metals. Welding of Nonferrous Metals, E. G. West. Sheet Metal Industries. vol. 25, no. 255 (July 1948), pp. 1405–1406, 1409; no. 256 (Aug.) pp. 1621–1626; no. 258 (Oct.) pp. 2046–2047; no. 259 (Nov.) pp. 2265–2268, 2271.

Oxygen Cutting. Three-Dimensional Flame-Cutting, O. L. Bailey. Welding Engr., vol. 33, no. 5 (May 1948), pp. 52–53.

Penstocks, Welded Steel. High Head Penstock Shop Welded and Field Riveted. Eng. News-Rec., vol. 141, no. 18 (Oct. 28 1948), pp. 88–89.

Petroleum Pipe Lines. Welded Aluminum Alloy Pipe Lines, B. J. Fletcher. Oil & Gas J., vol. 47, no. 21 (Sept. 23, 1948), pp. 207–208, 211, 301–302, 304.

Pipe Lines. Welded Pipelines, R. Hammond. Petroleum (Lond.), vol. 11, no. 11 (Nov. 1948), pp. 245–249.

Rails. Butt Welded Rail in Australia. Am. Ry. Eng. Assn.—Bul., vol. 50, no. 474 (June-July 1948), pp. 52–56.

Sewage Tanks. Small Welded Imhoff Tanks, J. I. Calahan. Sewage Works Eng., vol. 19, no. 9 (Sept. 1948), pp. 453–455.

Shaft Sinking. Wildwood Engineers Construct New Air Shaft, D. C. Jones. Mechanization, vol. 12, no. 10 (Oct. 1948), pp. 77–78, 80–81.

Shipbuilding. Highlights of Welded Ship Research, H. G. Acker. Soc. Naval Architects & Mar. Engrs.—Paper for meeting, Oct. 1948, 59 pp., 75c.

Tin Cans. Metal Container Manufacture. Sheet Metal Industries, vol. 25, no. 258 (Oct. 1948), pp. 1981–1988; no. 259 (Nov.) pp. 2206–2207.

Tubes. What User Should Know About Tubing, E. J. DeWitt. Am. Soc. Naval Engrs.—J., vol. 60, no. 4 (Nov. 1948), pp. 701–710.

Water Pipe Lines. Methods of Cutting Cast-Iron Pipe, S. L. Rogers. New England Water Works Assn.—J., vol. 62, no. 3 (Sept. 1948), pp. 238–241; see also Water & Sewage Works, vol. 95, no. 9 (Sept. 1948), pp. 308–309.

Welded Steel Structures, Stresses. Bending Tests of Large Welded-Steel Box Girders at Different Temperatures, A. H. Stang and B. S. Jaffe. U. S. Bur. Standards—J. Research, vol. 41, no. 5 (Nov. 1948) (RP 1934), pp. 483–495.

Welded Steel Structures. Welding Conserves Steel, T. R. Mullen. Eng. News-Rec., vol. 141, no. 18 (Oct. 28, 1948), pp. 104–105.

Welding. 1948 Products Reference Number. Welding Engr., vol. 33, no. 6A (Mid-June 1948), 152 pp.

Welds, Testing. Crack-Free Spot Welds, E. J. Clark. Welding Engr., vol. 33, no. 5 (May 1948), pp. 42–44.

Welds, X-Ray Analysis. Line Weld Checking With Portable X-Ray Unit, E. Sterrett. World Oil, vol. 128, no. 4 (Aug. 1948), pp. 195–196, 200–201.

lots of Drive

That's why P&H "AP" electrodes produce sound welds *in all positions* — *faster and at lower cost*

"AP" is a 6010 electrode that does most anything you ask of it — on production, construction, or maintenance work. The secret of its success lies in the drive of its spray-type arc. This drive gives you plenty of penetration — the kind of penetration that lets you weld in all positions with good speed and good results.

In addition to easy manipulation and speed, here are a few additional features that save welding time and money:

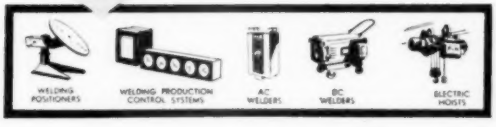
Good tensile strength and ductility — "AP" rods are especially suitable for work where tied-up stresses are involved.

Low spatter loss — The compounding of "AP's" special cellulose coating reduces spatter to a minimum.

Slag removal is quick and easy — "AP's" flat-shaped bead is covered with an unusually thin layer of slag that can be removed easily. This feature and the absence of spatter saves considerable cleaning time and assures better-looking jobs.

X-ray quality welds — Freedom from porosity is another important characteristic of "AP." That is why "AP" is the electrode to use when you desire a high-quality X-ray deposit.

Make a drive on your welding costs. Reduce them with P&H "AP" electrodes. Let your P&H representative or distributor show you why "AP" gets better results. Write us for literature.



P&H **Welding Electrodes**
4551 West National Avenue
Milwaukee 14, Wisconsin

HARNISCHFEGER CORPORATION

WELDING RESEARCH COUNCIL

of the Engineering Foundation

**Sponsored by the American Welding Society and American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers
American Society of Mechanical Engineers, and Society of Naval Architects and Marine Engineers**

Supplement to The Welding Journal, February 1949

The Work of the Ship Structure Committee

Introductory remarks by Rear Admiral Ellis Reed-Hill, Chairman, Ship Structure Committee, to open Symposium on Ship Structure Research, Annual Meeting, American Welding Society, Tuesday, Oct. 26, 1948.

THIS morning, I am experiencing for the Ship Structure Committee the satisfying feeling which comes to an actor or a musician when called back to the curtain for an encore.

Last year I appeared before this body at its annual meeting in Chicago to introduce the first Symposium on Ship Structure Research, which had been arranged through the courtesy of the AMERICAN WELDING SOCIETY in cooperation with the Ship Structure Committee. At that time a number of interesting and timely papers were presented by research investigators who had performed work which was under the cognizance of the Ship Structure Committee. Last year's program was so well received that before the annual meeting was concluded arrangements had been started, at the request of the AMERICAN WELDING SOCIETY, to present a second Symposium on Ship Structure Research at the annual meeting this year.

It is extremely gratifying to me to appear before you under such circumstances. The papers which will be presented today deal with subjects which are fully as pertinent and as timely as those which were presented last year, and they will be given to you by an extremely able group of Engineers and Scientists.

The Ship Structure Committee is, as you undoubtedly know, a cooperative effort on the part of the Army, Navy, Coast Guard, Maritime Commission and American Bureau of Shipping, to prosecute a research program to improve the hull structure of ships by an extension of knowledge pertaining to design, materials and methods of fabrication. In the pursuit of its mission, it is believed that the Ship Structure Committee achieved several notable steps during the past year. The most important in the opinion of the Committee is the promulgation by the American Bureau of Shipping of a new interim specification for ship steel which recognizes the need for control of the property: "notch sensitivity." This specification was made possible by data and other information evolved in studies conducted under the sponsorship of the Ship Structure Committee.

While the American Bureau of Shipping specification is based on chemical composition rather than physical performance, it is considered a step in the right direction and constitutes, therefore, the first milestone on the road to achievement of the goal, viz., a performance specification accompanied by a practical "mill type" test, which will adequately screen out all notch sensitive steels such as those which have been found at the origin of the fracture in every major ship casualty so far.

It is also noteworthy that the incidence of cumulative major failures on all welded ships has been reduced markedly by rounding the hatch corners and fitting a riveted gunwale. This record justifies the various structural changes made to combat the fracture menace.

Although the Ship Structure Committee has no direct administrative responsibility or authority in such matters, the information which the member agencies obtain through their membership in this joint committee is believed to have contributed to a large degree to the action taken early in 1948 requiring crack arrestors on all T-2 tankers and accelerating their installation. This program was highlighted and given added impetus by the complete structural failure of the T-2 tanker *Ponaganset*, while lying unloaded at a pier in Boston awaiting installation of the crack arrestors.

The increase in shipbuilding activities during the past

(Continued on page 88-s)

Fracture Characteristics of Ship Plate in Certain Small-Scale Tests*

By E. P. Klier,† F. C. Wagner† and M. Gensamer‡

In the present report the slow-bend notch-bar test previously discussed[3] is used to study more extensively the fracture characteristics of certain ship plate steels. Two notch radii, respectively, 0.01 and 0.0015 in., were used and numerous duplicate tests were run. The effects of fissuring and various normalizing temperatures have been in some measure studied. The results of edge-notched bar tensile tests are presented and discussed. It is shown that for the test bar used transition phenomena from shear to cleavage failure need not correlate with transition from tough to brittle behavior for the steels studied. The results of testing are discussed very briefly with reference to Davidenkov's[7] theory of failure.

Introduction

THE initial steps in the development of a small-scale, laboratory test, which would accurately indicate the fracture characteristics of large internally notched flat plate tension specimens,[1,2] have been reviewed in an earlier publication.[3] The flat plate specimens numbered, among others, 72-in. wide specimens. These 72-in. wide specimens were as large as could be tested conveniently under controlled laboratory conditions, and were sufficiently large to indicate, with assumed fair accuracy, the fracture characteristics of the steels in ship structures. The adequacy of this latter assumption has yet to be proved, however.

It has been generally assumed that the fracture characteristics of a series of steels will correlate in a series of pertinent tests. That this assumption is not generally correct, was pointed out in the earlier report.[3] This fact has also been pointed out in the evaluation of impact-test data obtained for varying notch geometry.[4] The failure of the standard Charpy test to correlate with the 72-in. wide plate tests led to the progressive modification of the testing procedure, with the development of a slow-bend notch-bar test. The final slow-bend test bar which has been used is a modification of the bar suggested by Schnadt,[5] because it allows ready access to the fracture surfaces for visual examination. The fracture characteristics of the steel can easily be determined from such examination, and it has been found that the transition temperature so determined is in excellent agreement with that obtained from lateral contraction measurements on this test bar.

In a further attempt to evaluate the fracture characteristics of the steels studied, an edge-notched tensile test, modified after Boodberg, *et al.* to suit a small tensile machine,[1] has been examined. A related test procedure has been investigated extensively by Barr and Tipper.[6]

Both Boodberg, *et al.*,[1] and Barr and Tipper,[6] have determined transition temperatures from fracture appearance in their notch-tensile tests. Barr and Tipper, in addition, have presented data on the yield point, ultimate strength, elongation and lateral contraction. These latter data do not, in all instances, show a transition from brittle to ductile behavior, which is particularly surprising for the elongation measurements. Since the elongation does not change abruptly through the critical range, as indicated by fracture type, it is necessary to conclude that energy absorption for the specimens tested below the transition temperature (by fracture appearance) has been high. Thus a cleavage type failure in this test need not, in general, be a brittle type failure. This conclusion is in essential conformity with the concepts of failure proposed by Davidenkov.[7] These concepts may be explained by means of Fig. 1.

Two quantities are defined by Davidenkov, in addition to the Ludwik[8] flow curve; namely a cleavage failure curve and a shear failure curve. It is postulated that fracture type is governed by the intersection of the flow curve with one or the other of the failure curves, being cleavage or shear for intersection with the respective curves.

From these considerations it follows that a fracture type can advantageously be described with reference to three criteria; namely, behavior, appearance and mode.*

* These designations are in current use in the Research Division of the Carnegie-Illinois Steel Corp.

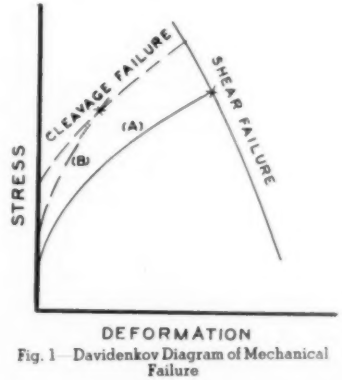


Fig. 1—Davidenkov Diagram of Mechanical Failure

* Presented before the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

The work reported here has been sponsored by the Ship Structure Committee, under Bureau of Ships Contract NObs-31217. The opinions expressed are those of the authors and are not necessarily those of the Ship Structure Committee or the Navy Department.

† Division of Metallurgy, The Pennsylvania State College, State College, Pa.

‡ Assistant to Director of Research, Carnegie-Illinois Steel Corp., Pittsburgh, Pa. Professor of Metallurgy and Head, Department of Mineral Technology, The Pennsylvania State College, State College, Pa., during the period in which this work was planned and in large part performed.

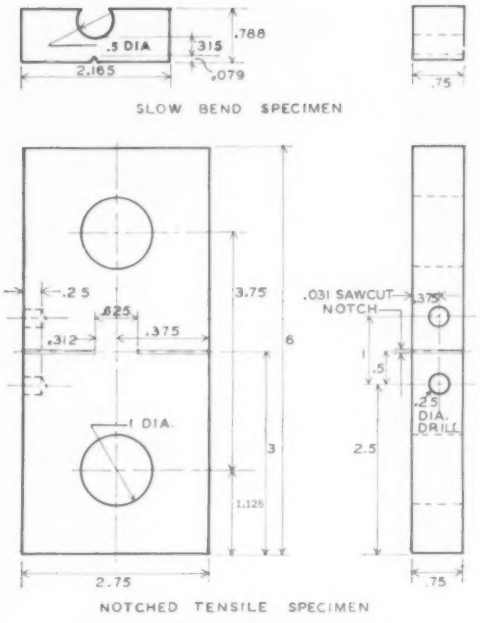


Fig. 2—Line Drawings of Test Specimens

These are respectively subdivided into tough and brittle, fibrous and granular (crystalline) and shear and cleavage.

The Testing Program

In order to eliminate as variables the directional properties of the plate, all of the specimens were of the same orientation in the plate.† For the slow-bend notch bars the long axis of the specimen was in the rolling direction, and the notch axis was in the thickness direction. The edge-notched tensile bars were loaded in the direction of rolling.

The program of tests was as follows:

A. Slow-Bend Notch-Bar Test for:
   1. 0.01-in. radius milled notch, 60 specimen sets.
   2. 0.0015-in. radius pressed notch, 60 specimen sets.
   3. $^1/_2$- and $^5/_8$-in. wide specimens, Steel A, with 0.0015-in. radius pressed notch.
   4. Miscellaneous tests, Steel Br.
   5. Miscellaneous tests, Steel Bn.
   6. Steels A, Br, Dr and E; annealed at 400° F. for 6 hr.

B. Edge-Notched Tensile-Bar Tests for:
   1. Available project steels.

† A slow-bend notch bar oriented with the long axis in the cross-rolling direction was studied, but the transition temperatures obtained for this orientation did not differ from those obtained for specimens oriented as described above.

Table 2—Gas Analyses of the Steels

Steels	N_2,* %	N_2† %	N_2,‡ %	N_2§ %	
A	0.004	0.004	0.004	0.0048	0.0048
Br	0.005	0.003	0.004	0.0040	0.0040
Bn	0.006	0.004	0.005	...	...
C	0.009	0.007	0.010	0.0094	0.0094
Dr	0.006	0.004	0.005	0.0046	0.0046
Dn	0.006	0.003	0.005	...	...
E	0.005	0.002	0.005	0.0034	0.0034
H	0.004	...	...	0.0044	0.0045
N	0.005	...	...	0.0048	0.0048
Q	0.006	...	...	0.0066	0.0065

* Bethlehem Steel Corp.
† Battelle Memorial Institute, Vacuum Fusion.
‡ Vanadium Corporation of America, H. Chandler.
§ Battelle Memorial Institute, Kjeldahl.

Steels

The chemical and gas analyses of the steels are presented in Tables 1 and 2, respectively.

Testing Procedure

Line drawings of the specimens tested are given in Fig. 2.

The slow-bend specimen is modified by having the compression zone drilled out. For testing, a hardened steel pin is inserted in this hole and the loading tup is made to bear on this pin. Since the test section of the specimen is under a tensile load, it separates entirely, even for a ductile break. A specimen with the pin in place ready for testing is presented in Fig. 3.

The tensile specimen is loaded through the pin holes by means of appropriate shackles.

Bend testing was conducted on a tensile machine by means of adapting fixtures, as indicated in Figs. 3 and 4. Specimens for testing were immersed in the liquid bath a minimum of 4 min. Since the time for testing one speci-

Table 1—Chemical Analyses of the Steels*

Steel	Thermal Treatment	C, %	Mn, %	P, %	S, %	Si, %	Al, %	Ni, %	Cu, %	Cr, %	Mo, %	Sn, %
A	As-Rolled	0.26	0.50	0.012	0.039	0.03	0.012	0.02	0.03	0.03	0.006	0.003
Br	As-Rolled	0.18	0.73	0.008	0.030	0.07	0.015	0.05	0.07	0.03	0.006	0.012
Bn plate 1	Normalized	0.18	0.73	0.011	0.030	0.04	0.013	0.06	0.08	0.03	0.006	0.015
Bn plate 2	.....	...	0.82	...	...	0.04	0.009	0.06	0.10	0.03	0.010	...
C	As-Rolled	0.24	0.48	0.012	0.026	0.05	0.016	0.02	0.03	0.03	0.005	0.003
Dr	As-Rolled	0.22	0.55	0.013	0.024	0.21	0.020	0.16	0.22	0.12	0.022	0.023
Dn	Normalized	0.19	0.54	0.011	0.024	0.19	0.019	0.15	0.22	0.12	0.021	0.025
E	As-Rolled	0.20	0.33	0.013	0.020	0.01	0.009	0.15	0.18	0.09	0.018	0.024
H	As-Rolled	0.18	0.76	0.012	0.019	0.16	0.053	0.05	0.09	0.04	0.006	0.004
N	As-Rolled	0.17	0.53	0.011	0.020	0.25	0.077	3.39	0.19	0.06	0.025	0.017
Q	1625° F., H_2O Quench—1300° F., 2 hr.	0.22	1.13	0.011	0.030	0.05	0.008	0.05	0.13	0.03	0.006	0.018

* Supplied by the Bethlehem Steel Corp.

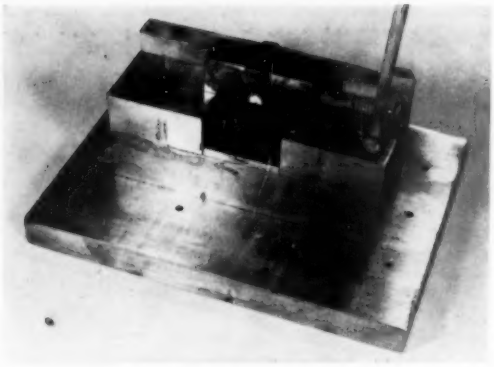


Fig. 3—Slow-Bend Fixture

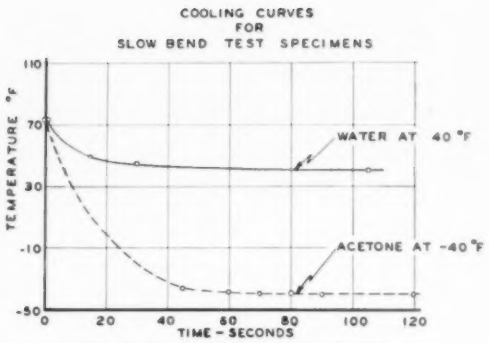


Fig 5—Cooling Curves for Slow-Bend Bar

men is approximately $^1/_2$ min., the testing was appreciably accelerated by the immersion of 6 specimens at a time. To ensure that the minimum holding time in the bath was sufficient to allow thermal equilibrium in the test bar, time-temperature curves for the mid-point in the critical cross section were obtained, and are presented in Fig. 5. It is evident that the specimen was at the temperature of the bath in approximately 1 min.

Tensile testing was conducted in an appropriate liquid bath. A wedge extensometer was used to obtain an autographic record of the load-elongation curve. The test setup and adapting fixtures are indicated in Figs. 6 and 7. To change specimens it was necessary to lower the container, Fig. 6. After the specimen and wedge extensometer were in place the container was raised as in Fig. 7. For temperatures below 32° F. the liquid used was acetone. This was cooled to the desired temperature with dry ice and held for 10 min. at temperature before testing. For temperatures above 32° F. the liquid bath was water.

Representation of Experimental Results

It has not been feasible in the slow-bend notch-bar test to make use of energy absorption measurements. However, such measurements would normally be too costly and time-consuming. Further, most standard recording equipment would require modification to allow such measurements, and there is appreciable plastic deformation under the specimen supports which should be eliminated if energy measurements were to be made. These difficulties are readily surmounted by the use of a different method of determining the transition temperature.

Two such methods have been extensively studied. The first of these consists in the measurement of the lateral contraction of the test bar in the critical cross section. There are three apparent locations where such a measurement might be made; namely, at the base of the notch, midway between the notch and the hole for the pin and adjacent to the hole. Results of measurements

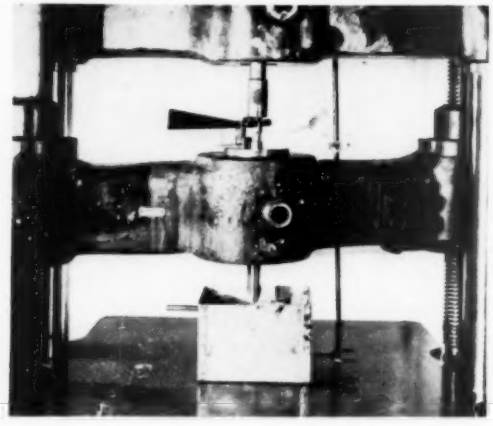


Fig. 4—Slow-Bend Testing Setup

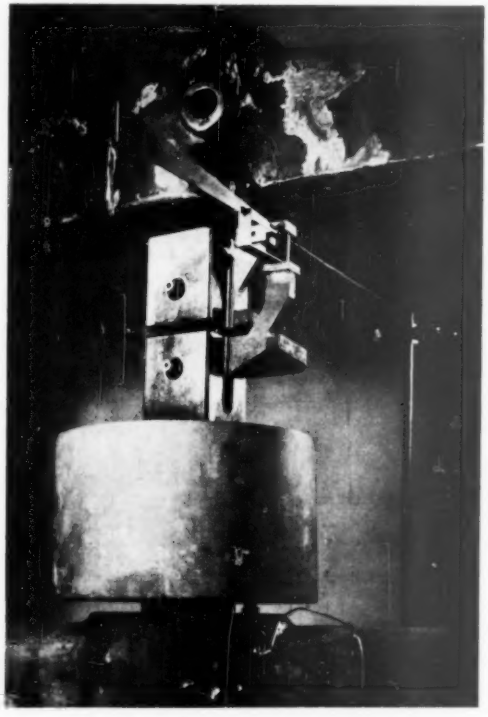


Fig. 6—Tensile Testing Setup. Container Down

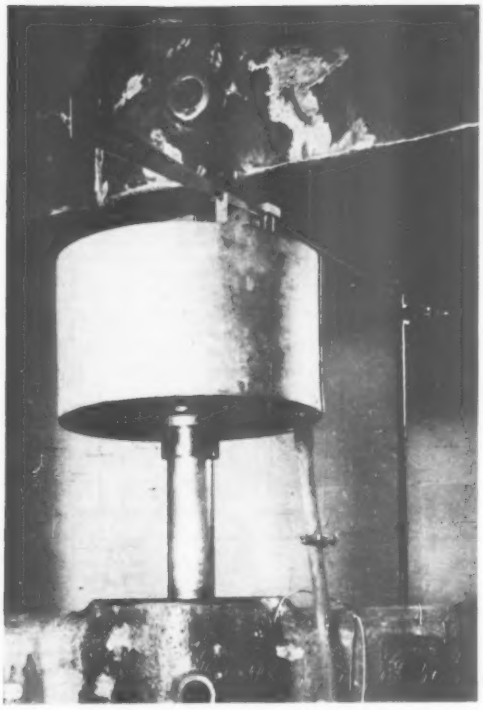


Fig. 7—Tensile Testing Setup. Container Up

at these three locations are presented in Fig. 8. Measurements at the base of the notch reveal a gradual drop in contraction with drop in temperature but the other two measurements reveal discontinuous transition ranges which are in close agreement. For convenience all measurements were subsequently restricted to the pin side of the specimen, because for this location it was not necessary to fit the broken halves of the specimen together. These measurements at the pin have been reported as $w_0 - w_1$ measurements, wherein w_0 and w_1 are the original and final lateral measurements.

On occasion, difficulty is experienced in obtaining a sharply defined transition range for $w_0 - w_1$ measurements, cf. Fig. 9. This effect has been observed only for steels with a high temperature transition range. At a high temperature in the brittle range a rim of metal is left after the brittle crack has formed and this rim fails in shear, as the test is completed. The failure of the rim in this manner results in appreciable lateral contraction for a failure that is essentially a brittle failure.

The second means available for determining the transition range depends on an evaluation of fracture type. The transition range for the slow-bend notch-bar test so established agrees in all important details with the transition range established by means of $w_0 - w_1$ measurements. The quantitative agreement of the two types of data is within 5° F. in most instances. Exceptions are observed however, for steels having a high temperature transition range. The fact that the transition range is easily determinable by visual inspection of the fracture surfaces marks this second procedure as the more convenient of the two procedures for general usage.

The test results have indicated that a transition range rather than a single transition temperature will be observed for most steels. For the slow-bend test this transition range is about 30° F. wide. Through the transition range, values are generally high or low with but few intermediate values being obtained. The transition curves which have been determined to date have not indicated for the number of specimens tested that a marked trend in the number of brittle or ductile failures exists from one end of the transition range to the other. As a consequence, the only fairly well defined points in the transition range appear to be the limiting temperatures of the range. Of these two temperatures it would seem that the higher is the more important. This temperature has been reported as the transition temperature.

The energy absorption, elongation, lateral contraction, fracture type, yield strength and tensile strength have been determined in the edge-notched tensile test. It has been found that there is not general agreement in transition temperatures for these test data. It has further been observed that two transitions are sometimes indicated. This may readily lead to conflict, in particular if these two transition temperatures are not separately defined. Seemingly a suitable way of surmounting this difficulty is to speak of two transition temperatures, one based on energy absorption measurements, the other based on fracture type. This point is more fully discussed in a subsequent section.

Throughout the report pertinent data have been presented in graphical form. Transition temperatures, as described above, are also tabulated. Microstructures have been presented in a limited number of cases.

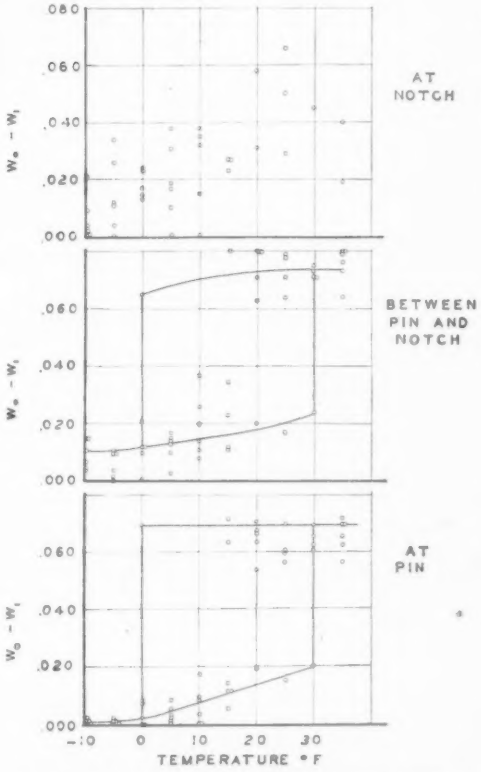


Fig. 8—Lateral Contraction Measurements at Three Locations on Test Section

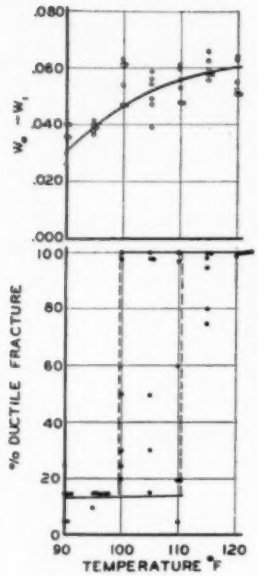


Fig. 9

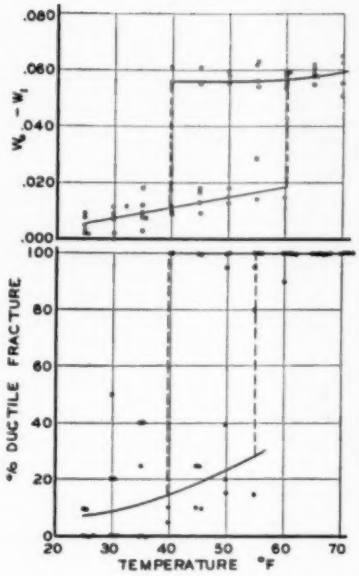


Fig. 10

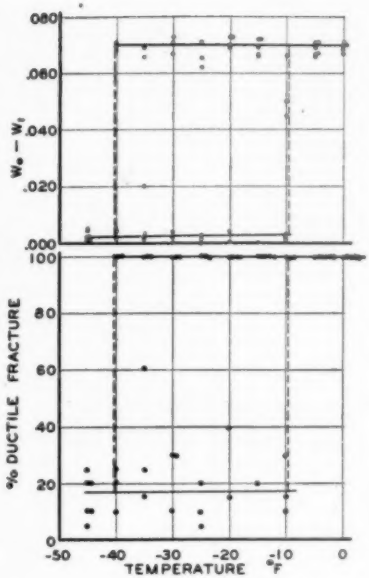


Fig. 11

Fig. 9—Lateral Contraction and Fracture Type Measurements for Steel E (Plate 17A1R). Notch Radius, 0.01 In.
Fig. 10—Lateral Contraction and Fracture Type Measurements for Steel A. Notch Radius, 0.01 In.
Fig. 11—Lateral Contraction and Fracture Type Measurements for Steel Br. Notch Radius, 0.01 In.

Experimental Results

A. Slow-Bend Tests

A—1, A—2—The results are presented graphically in Figs. 10 to 28. Transition temperatures are presented in Table 3.

The 0.01-in. radius notch is the standard milled Izod notch. The 0.0015-in. radius is a pressed notch after the method of Bagsar.[9] This notch was used to determine the effect of increased notch sharpness on the transition temperature, and, if possible, to restrict fissuring by increasing the notch severity. When the fracture surface exhibits fissures, lower transition temperatures are observed, presumably because the opening of the fissures diminishes the transverse tensile stresses and makes the notch provided by the advancing crack less severe. It would be expected that the results for Steel Br for the two notch radii would be markedly altered, if this effect was obtained. A comparison of Figs. 11 and 21 indicates that no pronounced shifting of the transition range results from using the pressed sharp notch. For Steel H, on the other hand, the transition temperature measured for the pressed notch is 20 to 25° F. higher than that for the milled notch. It must be concluded that the pressed notch is of limited value in suppressing the fissuring action.

Table 3—The Transition Temperatures* in Degrees Fahrenheit for the Slow-Bend Test

Steel	0.01-In. Radius Milled Notch $w_o - w_i$	0.01-In. Radius Milled Notch Fracture	0.0015-In. Radius Pressed Notch $w_o - w_i$	0.0015-In. Radius Pressed Notch Fracture	Large Plate† Results
A	60	55	65	65	35[1]
Br	−10	−10	0	0	30[1]
Bn	35	35	100	100	45[1]
C	120	125	..	130	95[1]
Dr	50	50	60	60	30[2]
Dn	40	40	30	30	30[2]
E	85	85	95	95	92[2]
H	−20	−25	0	0	20[1]
N	−20	−20	..	..	−40[1]
Q	0	0	−5	−5	..

* The highest temperature in the transition range.
† 50% energy absorption; superior figures are reference numbers.

As has been pointed out in an earlier section a discontinuance transition range is normally obtained with this test. Thus, over a range of temperatures both ductile and brittle failures may be obtained. It is not possible to satisfactorily account for this discontinuous transition range, but the data obtained for Steel E (Fig. 16, with a photograph of the specimens in Figs. 29(*a*), (*b*), (*c*)) indicate that the width of this transition range may be due to the action of large fissures. Thus, the single specimen tested at 60° F. which suffers appreciable lateral contraction in deeply fissured. On the other hand the single specimen which yields a high lateral contraction value for testing at 75° F. is not seriously fissured, indicating that the behavior here may be due to material variations rather than to a change in the stress system arising from fissuring. For this steel then it appears that the transition range would be about 10° F. wide in the absence of large fissures.

A wide transition range has not been indicated for the project steels in the earlier reports on the wide plate tests.[1, 2] More extensive testing in the 12-in. wide plate size reveals, however, that this wide transition range may exist much as has been observed for the slow-bend test data.[10]

The transition range normally is displaced to increasingly higher temperatures the more acute the notch. From the data of Zeno and Low,[11] however, it appears

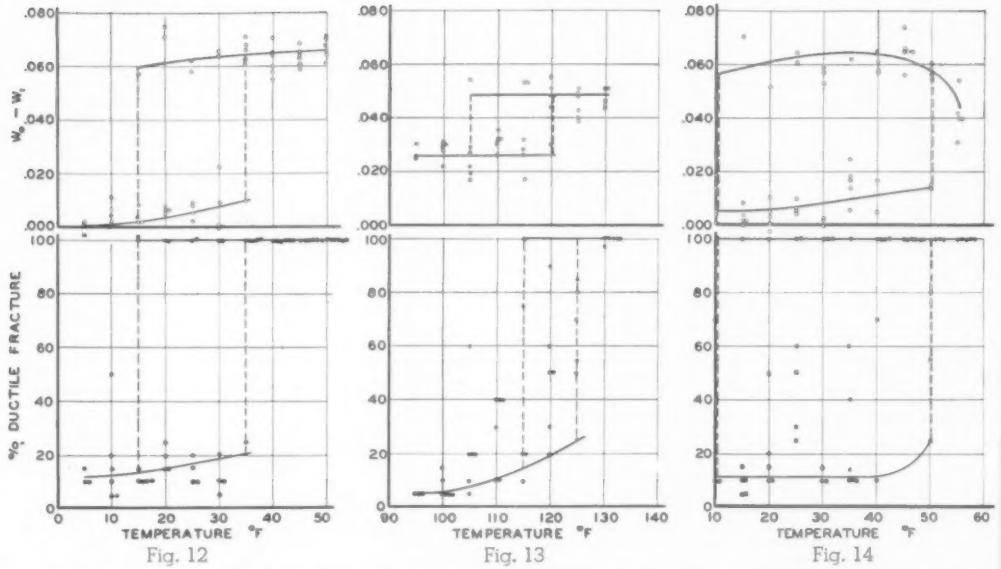


Fig. 12 Fig. 13 Fig. 14

Fig. 12—Lateral Contraction and Fracture Type Measurements for Steel Bn. Notch Radius, 0.01 In.
Fig. 13—Lateral Contraction and Fracture Type Measurements for Steel C. Notch Radius, 0.01 In.
Fig. 14—Lateral Contraction and Fracture Type Measurements for Steel Dr. Notch Radius, 0.01 In.

also probable that a limiting maximum temperature is approached as the notch becomes more acute. This supposition is sustained in part by the results obtained here. For example, the transition range is unaffected by the change from the milled to the pressed notch for Steel Dn (Figs. 15 and 25). For steels A, Br, Dr and Q it is also probable that positive elevation of the transition range does not exist. It is also pointed out that for steels which fissure due to the adverse strain state at the base of the pressed notch, an added cause for the elevation of the transition temperature might be expected. This factor may be responsible for the elevation of the transition temperature for Steel H.

It is believed, then, that in general the same results are

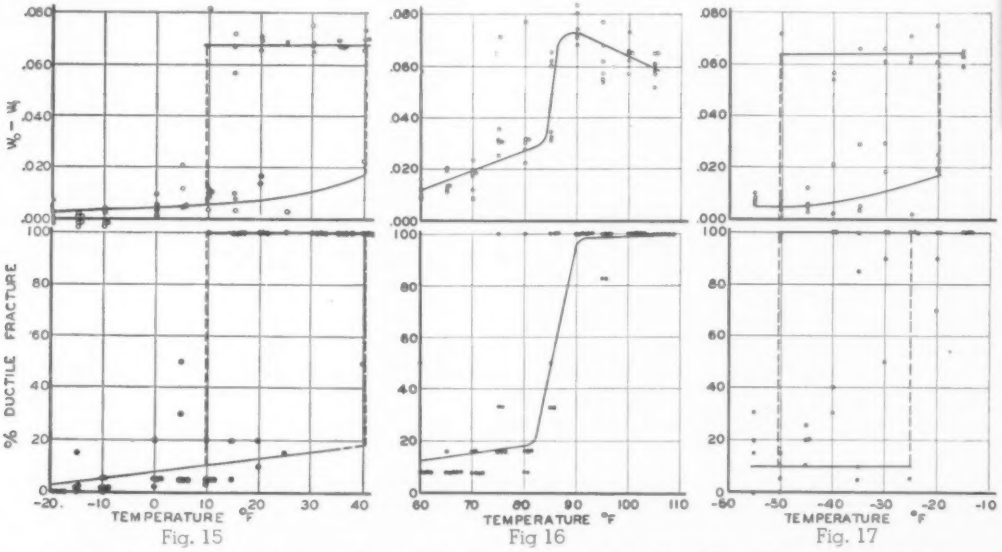


Fig. 15 Fig. 16 Fig. 17

Fig. 15—Lateral Contraction and Fracture Type Measurements for Steel Dn. Notch Radius, 0.01 In.
Fig. 16—Lateral Contraction and Fracture Type Measurements for Steel E. Notch Radius, 0.01 In.
Fig. 17—Lateral Contraction and Fracture Type Measurements for Steel H. Notch Radius, 0.01 In.

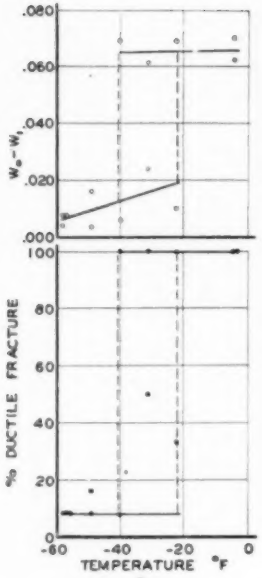


Fig. 18

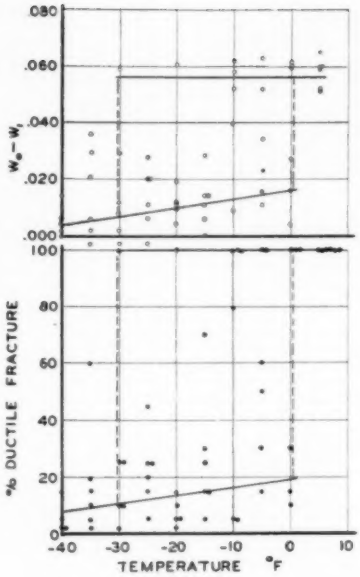


Fig. 19

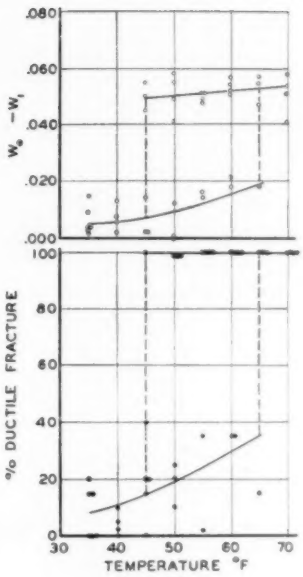


Fig. 20

Fig. 18—Lateral Contraction and Fracture Type Measurements for Steel N. Notch Radius, 0.01 In.
Fig. 19—Lateral Contraction and Fracture Type Measurements for Steel Q. Notch Radius, 0.01 In.
Fig. 20—Lateral Contraction and Fracture Type Measurements for Steel A. Notch Radius, 0.0015 In.

obtained for the pressed notch as for the milled notch, but in those instances where differences arise they may result in an improvement in the accuracy of the test when the pressed notch is used. For those data presented in Figs. 23 and 26 for $w_1 - w_i$ measurements it is reiterated that these data are in conflict with the fracture type data due to the intrusion of the phenomenon previously discussed with reference to Fig. 9. It would appear that the fracture type data more properly indicate the behavior of the steel in these instances.

The conditions under which the 0.0015-in. radius notch is formed in the test bar are so severe that specimens have been observed to fail by the initiation first of a cleavage failure which after progressing a short distance changes to a shear failure, Fig. 30. This behavior is contrary to what would be expected from previous experience. This is evidently traceable to the highly localized plastic deformation which accompanies the formation of the pressed notch. The cleavage crack once started has been propagated an appreciable distance into the specimen away from the affected zone under the notch before it has changed to a shear type crack.

From Table 3 it is evident that the transition temperatures obtained by the slow-bend test are in satisfactory agreement with the results of 72-in. wide plate testing, except for those transition temperatures obtained for

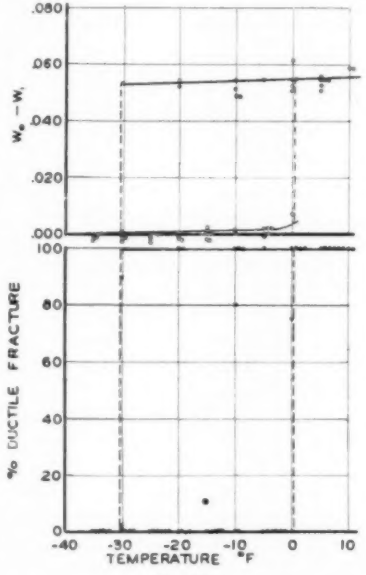


Fig. 21

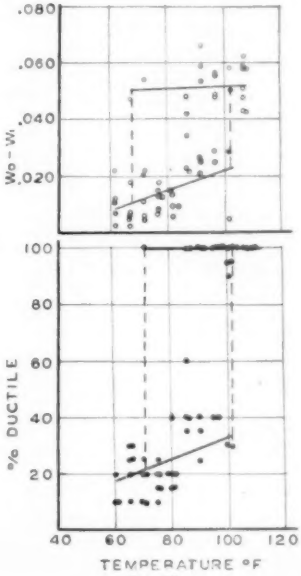


Fig. 22

Fig. 21—Lateral Contraction and Fracture Type Measurements for Steel Br. Notch Radius, 0.0015 In.
Fig. 22—Lateral Contraction and Fracture Type Measurements for Steel Bn. Notch Radius, 0.0015 In.

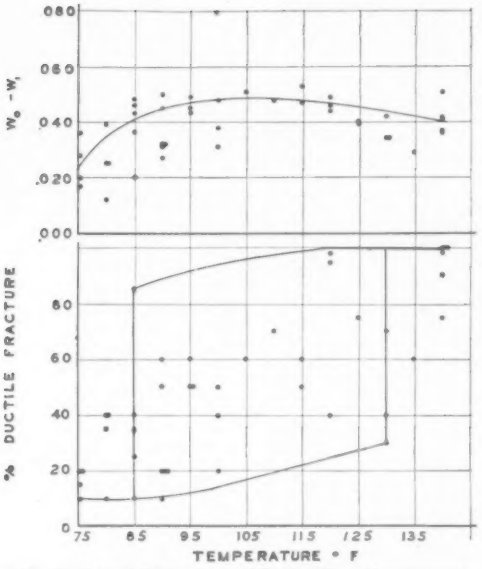


Fig. 23—Lateral Contraction and Fracture Type Measurements for Steel C. Notch Radius, 0.0015 In.

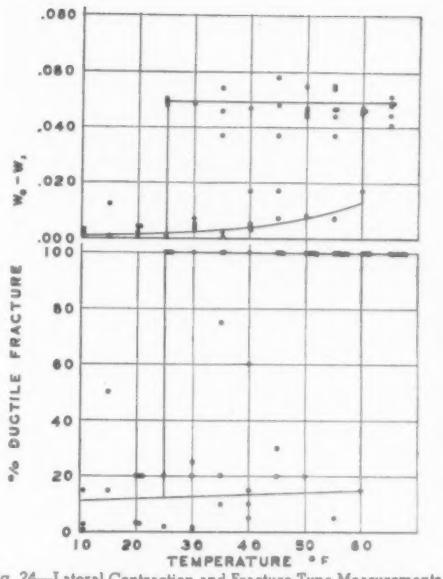


Fig. 24—Lateral Contraction and Fracture Type Measurements for Steel Dr. Notch Radius, 0.0015 In.

steels Br, H for the 0.01 in. radius notch and for steel Bn for the 0.0015 in. radius notch. The results obtained for the first two steels, as well as certain data obtained for Steel Bn will be more fully discussed in subsequent sections.

A—3.—It is known that the transition temperature is modified by the width of the specimen tested.[12] Further, the modification of the transition temperature by the width of the specimen is affected by the height of the specimen.[13] As might be expected this interrelationship of specimen width and height factors is complex and cannot generally be anticipated. For the steels which are under examination this interrelationship, which is studied as a function of width of the test bar alone as the height remains constant, becomes important due to the existence of fissures in the test sections. When these fissures are extensively developed it appears that the effective width of the specimen is reduced by approximately one-half. In order that the action of these large fissures might be examined specimens of Steel A were machined from the center of $^3/_4$-in. plate to $^5/_8$ and $^1/_2$ in. widths. These specimens were the same in other dimensions as the Schnadt-type bar with 0.0015-in. radius pressed notch.

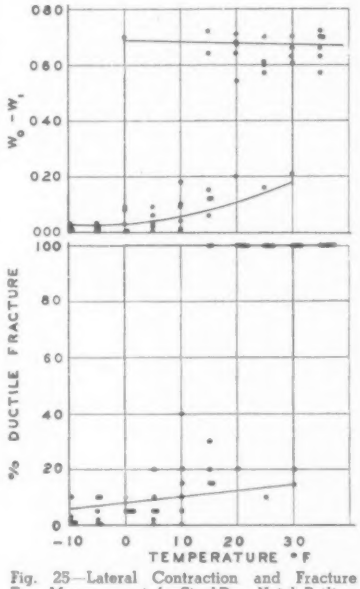


Fig. 25—Lateral Contraction and Fracture Type Measurements for Steel Dn. Notch Radius, 0.0015 In.

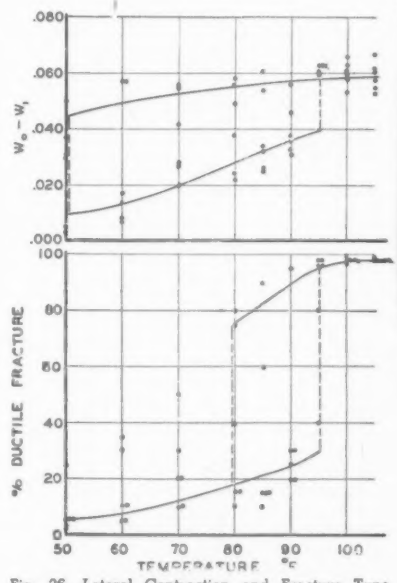


Fig. 26—Lateral Contraction and Fracture Type Measurements for Steel E. Notch Radius, 0.0015 In.

The test results for these test specimens are presented in Figs. 31 and 32. It is apparent from a comparison of these data with the test results in Fig. 20 that no appreciable variation in the transition temperature results from this reduction in specimen width.

It is not to be concluded, however, that specimen width is an unimportant factor in so far as the transition data are concerned. This is notably emphasized by the photograph of the fracture in a specimen of Steel Dr

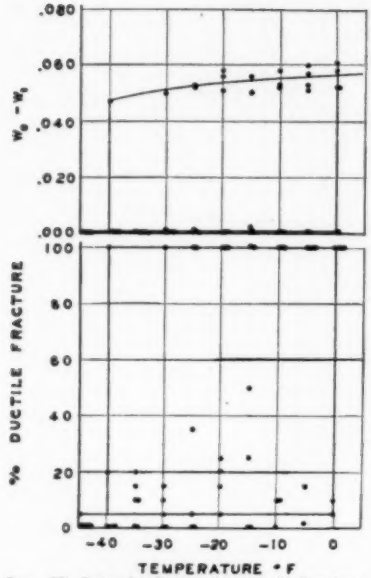


Fig. 27—Lateral Contraction and Fracture Type Measurements for Steel H. Notch Radius, 0.0015 In.

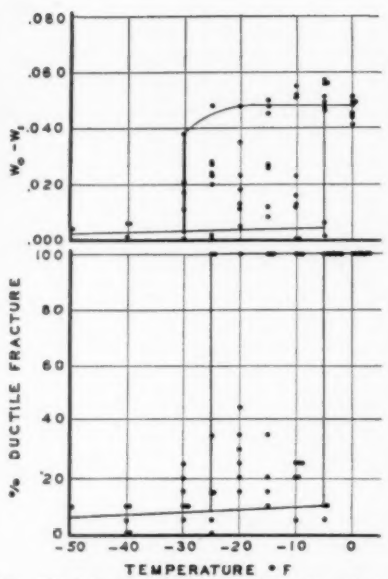


Fig. 28—Lateral Contraction and Fracture Type Measurements for Steel Q. Notch Radius, 0.0015 In.

presented in Fig. 33. This specimen was tested in the transition range. In the course of the development of the crack from under the notch, two fissures opened up, one each at the quarter and mid-points in the section. The fissure-free half of the specimen failed by a cleavage failure, while the other half of the specimen failed by a shear failure. Evidently the fissuring of the second half of the specimen caused a decrease in the intensity of the stress system at the tip of the crack and a consequent decrease in the transition temperature for this half of the specimen.

It would appear from these data and from the results for Steel E, Figs. 16 and 29(*a*), (*b*), (*c*), that a decrease in specimen width to below $^1/_2$ in. would cause a measurable lowering of the transition temperature. At widths of $^1/_2$ to $^3/_4$ in., for the test bar studied there appears to be no modification of the transition temperature due to variation in width.

A—4.—An examination of the fractures for specimens of steels Br and H revealed that these steels did not, for the most part, fissure in the same manner as did the other steels. For steels Br and H the fissures were relatively small and closely spaced. This phenomenon has been used to explain the fact that the slow-bend test has not satisfactorily predicted the large plate behavior of these steels.[3] Subsequent testing has served to strengthen this conclusion.

For example, steel from three plates of Steel Br was available for testing. These plates consisted of (1) the original stock available for slow-bend testing, (2) a section from a 72-in. wide test plate and (3) three sections from a plate being tested at Swarthmore College. The test data for the first two plates are presented in Fig. 34. It is evident that the transition temperatures for the two plates are in complete disagreement. Because of the unknown strain history for plate B-1-A, the results for this plate can be accepted only with reservations, although it had appeared that this material had not been extensively prestrained.

The test data for the third plate of Steel Br are presented in Figs. 35 and 36. These data do not agree with the data obtained initially for Steel Br. Further, these latter specimens do not show the tendency for developing a large number of small fissures, although one set of specimens showed a pronounced tendency to develop large fissures. From the absence of the small fissures it would be anticipated that the transition ranges for these last sets of specimens would be appreciably increased, and this is found to be the case. Thus, the transition temperature of this steel has been measured from −10 to +40° F. and there is apparent correlation between the transition temperature and the degree of fissuring. From these data it appears that the fissured condition is not typical for Steel Br and from this it would follow that the low transition temperature is not typical. Finally, when the small fissures are not present the transition temperatures measured with the slow-bend test are in satisfactory agreement with those measured from the 72-in. wide internally notched plate tension specimens.

Additional plates of Steel H have not been available for testing.

A—5.—Two plates of Steel Bn were available for slow-bend testing. A set of specimens was cut from the second plate and the transition temperature was determined for this second plate. The data are presented in Fig. 37. It is evident from a comparison of these data with those presented in Fig. 12 for Steel Bn, plate 1, that this second plate is seriously different from the original plate of Steel Bn. This difference is so marked that it was thought that the steel was improperly identified. To check the identity of the plate an analysis was obtained and is presented in Table 1. From a comparison of the percentages of the residual elements it is almost certain that this second plate is Steel Bn. Further justification of this conclusion is afforded by the test results for the 0.0015 in. radius pressed notch, cf. Fig. 22.

In an effort to determine the reason for the appreciable increase in the transition temperature of this plate of Steel Bn it was decided that a study of the effects of normalizing should be made.* Specimens of Steel Bn, plate 1, were normalized from 1550, 1600, 1650 and 1700° F. The transition data are presented in Figs. 38–43. Additional sets of specimens were run at 1600 and 1650° F. to check the results obtained initially. The data presented here have been obtained for small specimens which have a relatively high rate of cooling from the normalizing temperature. Since the cooling rate effect has not been evaluated, the normalizing effect indicated here cannot be translated directly to larger sections. It may be expected for larger sections but possibly displaced to different temperatures. The dis-

*This experimentation was suggested by Dr. J. R. Low, Jr., The Pennsylvania State College.

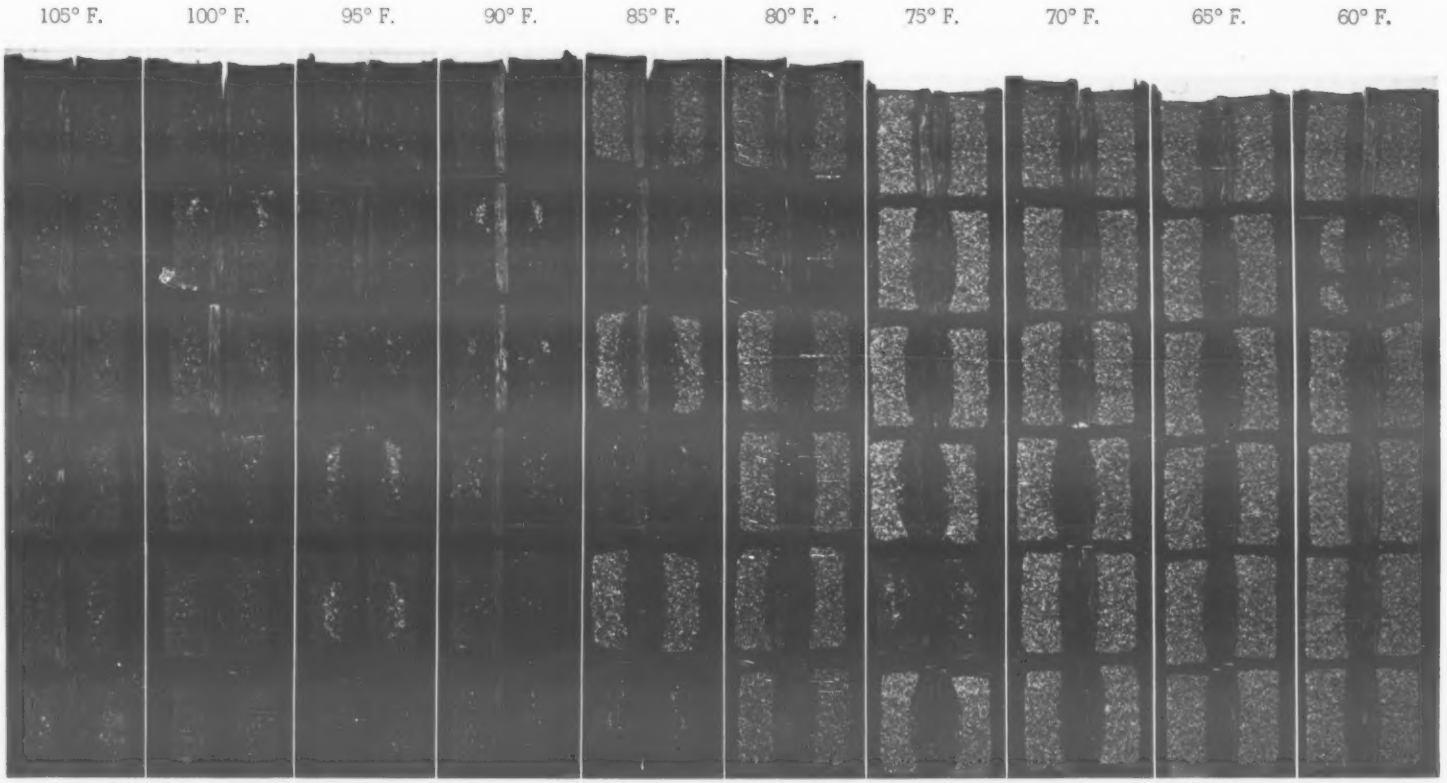


Fig. 29—Fracture Steel E

placement of the transition temperature in these experiments amounts to about 50° F. The variation with the normalizing temperature is not considered significant in the light of the scatter in transition temperature measurements with this steel.

Photomicrographs for the specimens which received the various normalizing treatments are presented in Fig. 44. There appears to be no relationship between the microstructures observed and the transition temperatures obtained.

A—6.—It has been suggested that certain of the differences in the transition temperatures for the project steels might be due to differences in their respective hydrogen contents. In an admittedly inadequate attempt to check this possibility specimens of steels A, Br, Dr and E were heated to 400° F. for 6 hr. It was thought that this treatment was possibly the best considering the time available for this study, to indicate any possible effect resulting from hydrogen removal.

The transition temperatures obtained for these specimens are presented in Table 4. The data for Steel Br are presented in Fig. 45. The curves for the other steels conform with those presented in Figs. 20, 24 and 26, respectively. This treatment has lowered the transition temperature for Steel Br by about 20° F. The other steels are unaffected by the treatment. A set of specimens of Steel Br was then normalized from 1650° F. The data for these specimens are presented in Fig. 46. The transition temperature has been drastically lowered by this treatment which would not be expected to lower the hydrogen content of the steel. The slight improvement in one steel resulting from the low temperature

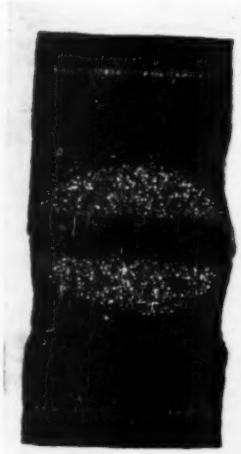


Fig. 30—Fracture in Steel Dr, Showing Change from Cleavage to Shear Failure

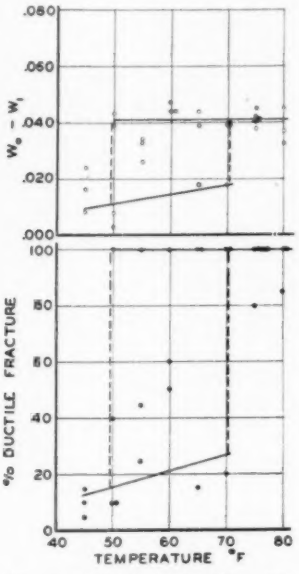


Fig. 31—Lateral Contraction and Fracture Type Measurements Steel A. Specimen Width 1/2 In. Notch Radius, 0.0015 In.

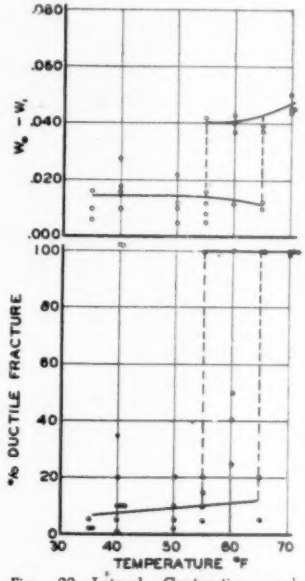


Fig. 32—Lateral Contraction and Fracture Type Measurements Steel A. Specimen Width, 5/8 In. Notch Radius, 0.0015 In.

Fig 33—Fracture in Steel Dr, Showing One-Half Cleavage and One-Half Shear Failure

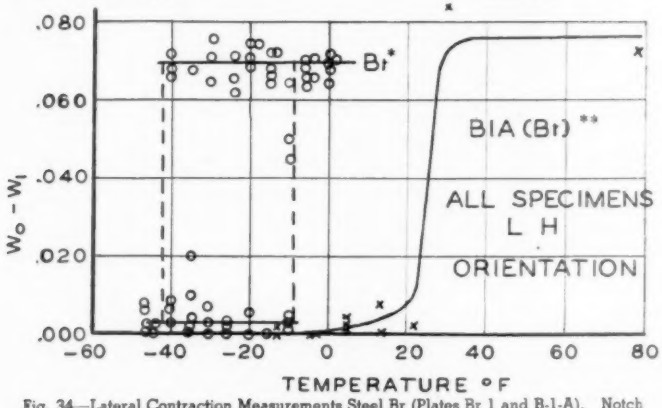


Fig. 34—Lateral Contraction Measurements Steel Br (Plates Br 1 and B-1-A). Notch Radius, 0.01 In.

*Data presented in Figure 11.
**Data obtained with Specimens from large Plate Section.

Table 4—The Transition Temperatures* in °F. for the Slow-Bend Test for Specimens at 400° F. for 6 Hr. 0.0015-In. Radius Pressed Notch

Steel	$w_0 - w_1$	Fracture
A	65	65
Br	−40	−40
Dr	45	45
E	100	100

* The highest temperature in the transition range.

treatment can hardly be considered good evidence for any effects due to hydrogen.

B. Edge-Notched Tensile Tests

The edge-notched tensile specimens investigated by Boodberg, *et al.*,[1] were 3 in. in nominal width by nominal plate thickness. This specimen cannot be broken on the 60,000-lb. testing machine which was available for this testing program. Preliminary tests indicated that the test specimen presented in Fig. 2 could be handled satisfactorily.

The effect of notch geometry was briefly studied, but was not completed because of lack of material. The brief survey which was conducted indicated that the transition temperature, as determined from fracture appearance, was constant for the 3 notch forms studied. These notch forms were a $^1/_{32}$-in. saw cut, a $^1/_{32}$-in. saw cut terminating in a $^5/_{64}$-in. diam. drilled hole and a 0.01-in. radius V-notch, 45° included angle. The $^1/_{32}$-in. saw cut notch was used in subsequent work, as this notch was the most simple to machine.

B-1.—The results of edge-notched tension testing are presented in Figs. 47 to 52 and in Table 5. In the figures, transition temperatures are indicated by arrows.

The data for fracture type (Fig. 47) in each instance define a straight-forward transition range. Transition temperatures were taken as those points which correspond to a 50% fibrous fracture, except for Steel Dn for

Table 5—The Transition Temperatures in °F. for the Edge-Notched Tensile Test

Steel	By Fracture Type	By Energy Absorption	By Lateral Contraction	By Elongation
A	90	..	110	..
Br	−30	−40	−35	−40 (?)
Bn[2]	90	..	75	..
C	130	30 (?)	115	30
Dr	75	−45 (?)	−60 (?); 75	45
Dn	35	−55 (?)	40	−60
E	100	..	10; 100	120
H	75	..	−75 (?)	..
Q	50	−35 (?)	..	..

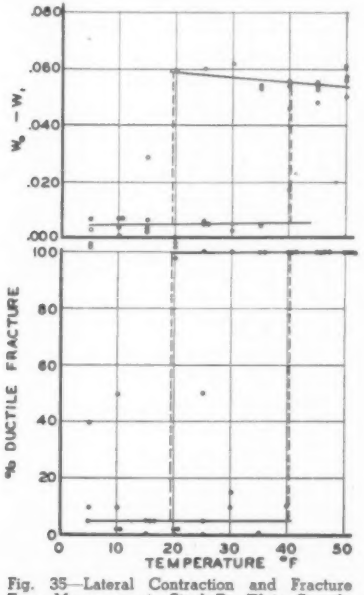


Fig. 35—Lateral Contraction and Fracture Type Measurements Steel Br (Plate Swarthmore 1). Notch Radius, 0.0015 In.

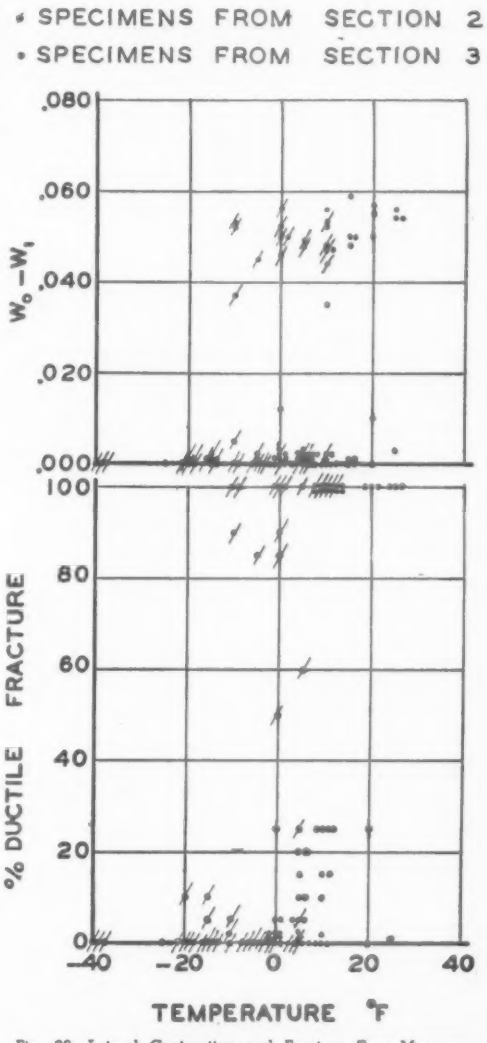


Fig. 36—Lateral Contraction and Fracture Type Measurements Steel Br (Plate Swarthmore 1; Sections 2 and 3). Notch Radius, 0.0015 In.

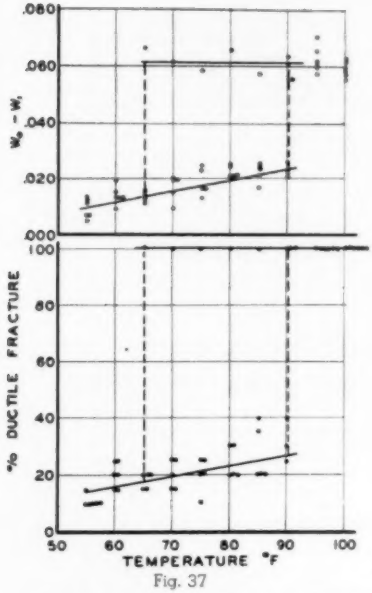


Fig. 37

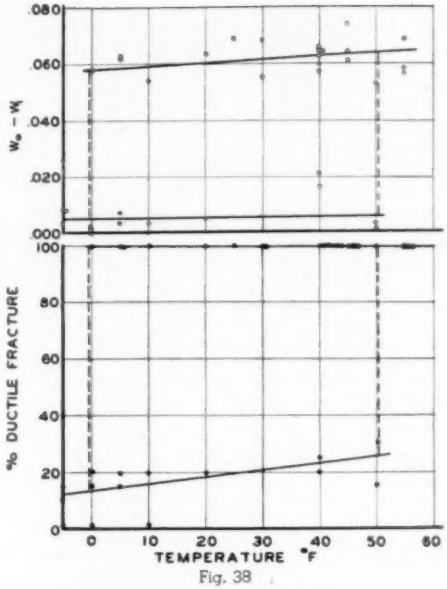


Fig. 38

Fig. 37—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 2). Notch Radius, 0.01 In.
Fig. 38—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 1). Normalized from 1550° F. Notch Radius, 0.0015 In.

which the transition temperature was taken as the mean temperature in the transition range.

The energy absorption data (Fig. 48) are difficult to interpret, as frequently they do not reveal a transition from a ductile to a brittle failure despite the evidence offered by fracture appearance. Further, when a transition range is revealed, it is not, in general, in agreement with that obtained from fracture appearance. The numerical differences in the transition temperatures by the two methods may be of the order of 100° F. For Steel Br alone correlation obtains for the two procedures.

It is to be concluded from these data that for the edge-notched tension test correlation does not exist between the transition temperatures determined from fracture appearance and from energy absorption measurements. Despite this, as is evident from Table 5, the transition temperatures obtained from fracture appearance data are in good agreement with the results obtained in the 72-in. wide internally notched plate tension tests.

The lateral contraction measurements (Fig. 49) and elongation measurements (Fig. 50) are particularly interesting in that they sometimes indicate two transition ranges. Most pronounced in this respect are the elongation data for Steel Dr and the lateral contraction data for Steel E. For these sets of data the high temperature transition correlates with fracture data, while the low temperature transition correlates with energy absorption data. In general, however, it cannot be said that two clearly defined transition ranges exist—a fact that in all probability results from the limitations in the temperature range studied. Thus, it is known that for steels Bn plate 2 and E the indicated transition effects for elongation measurements are to be correlated with fracture appearance because of the high strain values that are obtained below these transition ranges. This high strain value must disappear at sufficiently low temperatures, as the steels ultimately become completely brittle, and there can be no appreciable energy absorption once this brittle state is attained. This lower transition in elongation measurements must correlate with energy absorption.

The transition effects for lateral contraction measurements are frequently pronounced at the high temperature

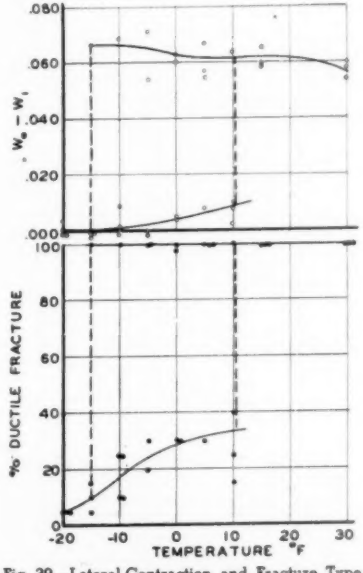


Fig. 39—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 1). Normalized from 1600° F. Notch Radius, 0.0015 In.

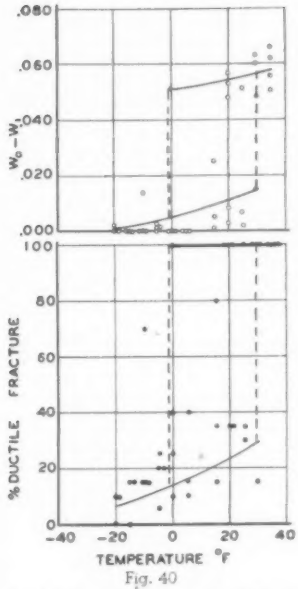


Fig. 40

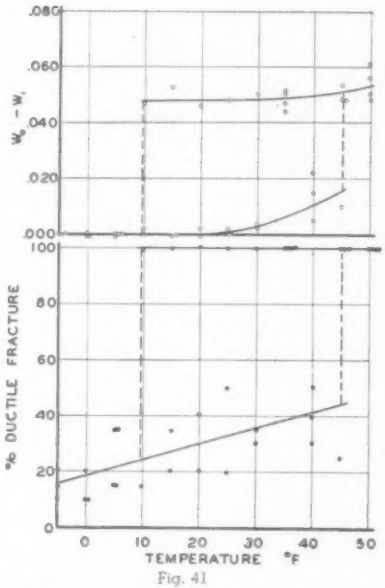


Fig. 41

Fig. 40—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 1). Normalized from 1600° F. Notch Radius, 0.0015 In.

Fig. 41—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 1). Normalized from 1650° F. Notch Radius, 0.0015 In.

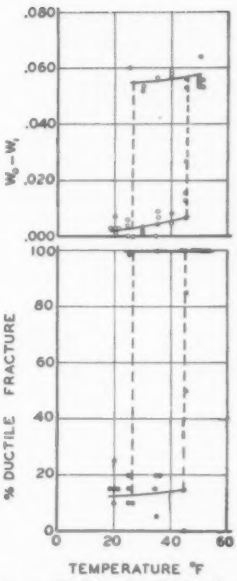


Fig. 42—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 1) Normalized from 1650° F. Notch Radius, 0.0015 In.

level, cf. steels Br, Bn plate 2, Dr, Dn and E, Fig. 49. When this condition exists excellent agreement obtains between the transition temperature indicated and that determined from fracture appearance, cf. Table 5. However, the determination of transition effects by lateral contraction measurements is not unambiguous in all instances, as is indicated by the data for steels A, C, H and Q.

Discussion

The data which have been obtained for the slow-bend notch-bar tests for lateral contraction measurements and for fracture appearances establish a transition range and temperature for the respective steels which is in good agreement with the large-scale test data. In no instance has there been a serious discrepancy in the slow-bend transition data by the two methods of representation. This is not so, however, for the results of edge-notched bar tension testing.

The experimental results for the edge-notched bar tensile test and for the slow-bend test may be considered with reference to Davidenkov's failure mechanism. It is pointed out that this failure mechanism is phenomenological in character, and so the respective flow and fracture curves must be determined experimentally. The fracture curves, in particular, cannot be drawn from any theoretical bases.

The flow curves in Fig. 1 are drawn to indicate the instantaneous stress on the test section. The stress increases continuously to the point of failure. In Fig. 1 the curvature of the cleavage fracture curve is such that a particular flow curve can be drawn to intersect it at each strain value to that at which the cleavage fracture curve is crossed by the shear fracture curve. From this it would be expected that for a test which conformed to this representation no break in the energy absorption vs. temperature curve—the energy absorption being measured as the area under the flow curve—would be found. This is seen to be the case for the notched-bar tensile test reported here.

For the slow-bend test, however, it has been indicated

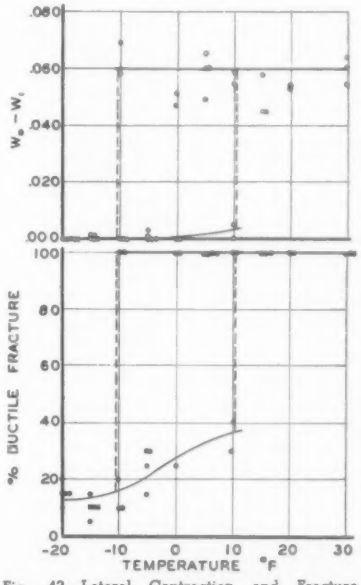
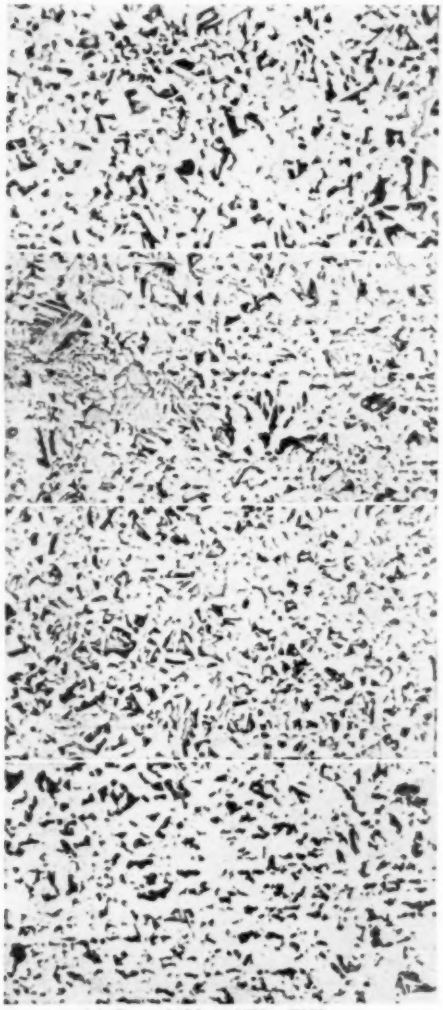


Fig. 43—Lateral Contraction and Fracture Type Measurements Steel Bn (Plate 1). Normalized from 1700° F. Notch Radius, 0.0015 In.

that the energy absorption values (as indicated by lateral contraction values) may be discontinuous with temperature. For this to be true, it is necessary that the Davidenkov diagram be modified, and such a modification as indicated in Fig. 53 satisfactorily accounts for the behavior of the slowbend test. For this construction the test section is represented as failing by cleavage failure at low strain values. As is evident, the flow curve cannot cut the cleavage fracture curve at the intermediate strain levels which are denoted as the range $\Delta\epsilon$ in the figure. As a consequence of this—on the assumption that the representation is correct—failure cannot occur until the strain equals that given by the intersection of the appropriate flow curve with the shear fracture curve. Since the areas under the flow curves change discontinuously through this range, the energy absorption in the test changes discontinuously. In this way also some of the discontinuous energy absorption curves obtained in the impact test[14] may be explained.



(a) Air cooled from 1700. X100.
(b) Air cooled from 1650. X100.
(c) Air-cooled from 1600. X100.
(d) Air-cooled from 1550. X100.

Fig. 44—Photomicrographs of Steel Bn (Plate 1). After Normalizing from Different Temperatures

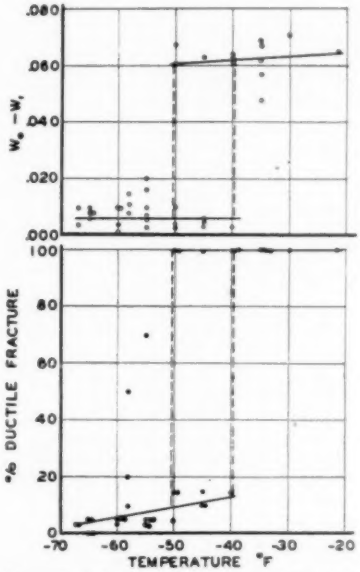


Fig. 45—Lateral Contraction and Fracture Type Measurements Steel Br. Annealed at 400° F. for 6 Hr. Notch Radius, 0.0015 In.

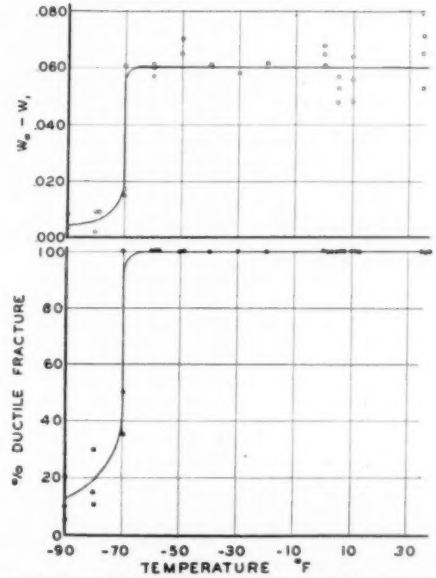


Fig. 46—Lateral Contraction and Fracture Type Measurements Steel Br. Normalized from 1650° F. Notch Radius, 0.0015 In.

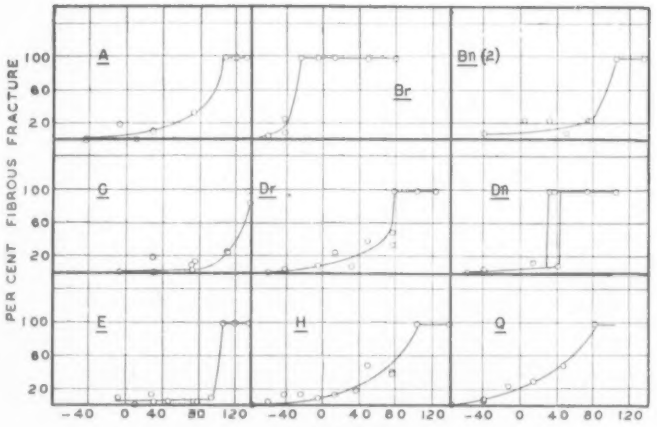


Fig. 47—Edge-Notched Tensile Test Data for Fracture Type Measurements

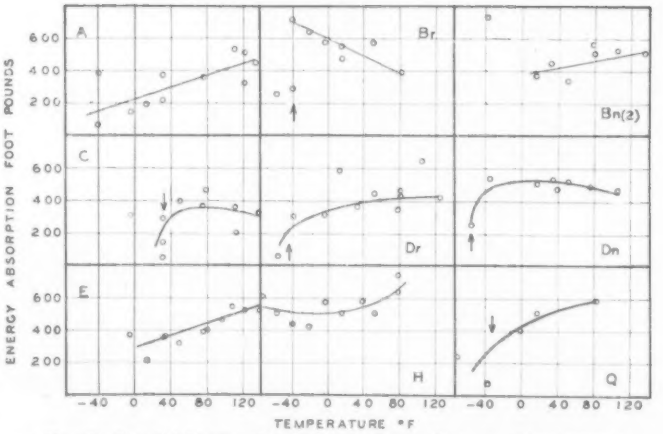


Fig. 48—Edge-Notched Tensile Test Data for Energy Absorption Measurements

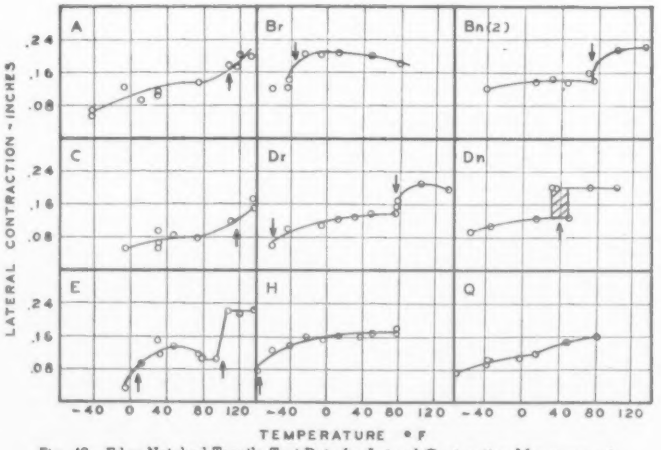


Fig. 49—Edge-Notched Tensile Test Data for Lateral Contraction Measurements

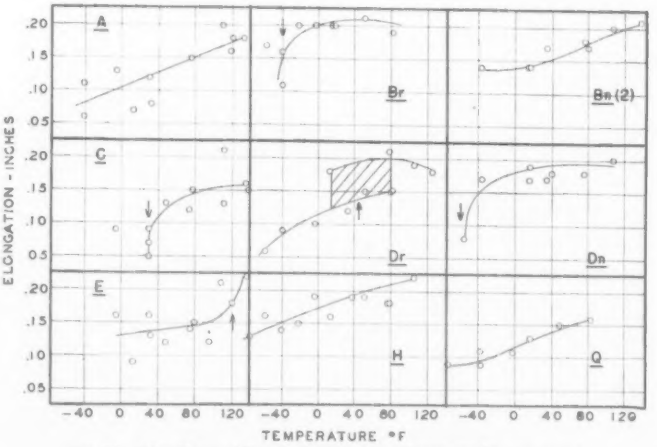


Fig. 50—Edge-Notched Tensile Test Data for Elongation Measurements

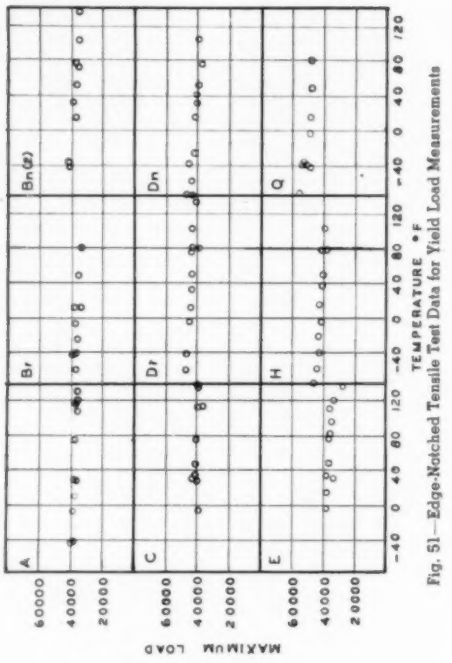


Fig. 51—Edge-Notched Tensile Test Data for Yield Load Measurements

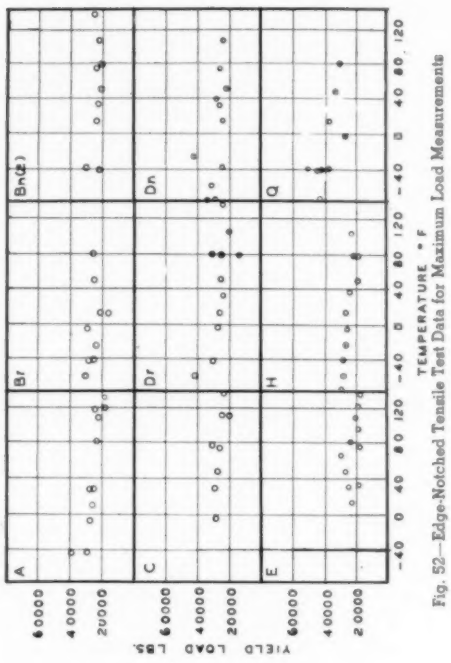


Fig. 52—Edge-Notched Tensile Test Data for Maximum Load Measurements

Conclusions

1. It has been shown that the slow-bend notch-bar testing procedure using the Schnadt-type bar with a pressed notch of 0.0015 in. root radius, 45° included angle, for the most part yields satisfactory fracture data for correlation with the 72-in. wide internally notched plate data.

2. Added information concerning the effect of specimen width has been obtained. These data indicate that the transition range should be relatively insensitive to width so long as the width is between $^1/_2$ and $^3/_4$ in.

3. It has been possible for Steel Br to obtain correlation between the slow-bend notch-bar test and the 72-in. wide plate test results, when fissure-free sections of plate were tested.

4. For the edge-notched bar tension tests two transition ranges are observed—one associated with change in fracture type, the other with drop-off in energy absorption. The transition temperature determined from fracture appearance is in approximate agreement with the 72-in. wide plate test results, while that determined from energy absorption measurements is not.

5. These results have been discussed in the light of Davidenkov's modification of Ludwik's theory of failure, with which, phenomenologically, they in part agree.

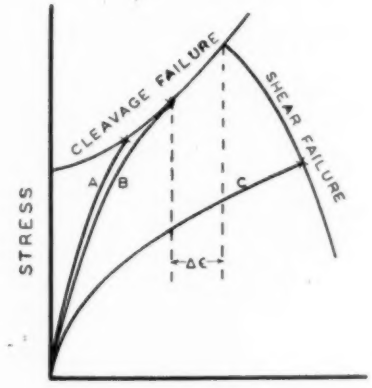


Fig. 53—Modified Davidenkov Diagram of Failure for Slow-Bend Test

References

1. Boodberg, A., Davis, H. E., Parker, E. R., and Troxell, G. E., "Causes of Cleavage Fracture in Ship Plate—Tests of Wide Notched Plates," THE WELDING JOURNAL, **27** (4), Research Suppl., 186-s to 199-s (1948).
2. Wilson, W. M., Hechtman, R. A., and Bruckner, W. H., "Cleavage Fracture of Ship Plates as Influenced by Size Effect," *Ibid.*, **27** (4), Research Suppl., 200-s to 207-s (1948).
3. Klier, E. P., Wagner, F. C., and Gensamer, M., "The Correlation of Laboratory Tests with Full Scale Ship Plate Fracture Tests," *Ibid.*, **27** (2), Research Suppl., 71-s to 96-s (1948).
4. Schiffler, H. J., Discussion "Steels for Use at Low Temperatures and Their Testing," by H.-J. Wiester, *Stahl u. Eisen*, **63**, 69 (1943).
5. "The Notched-Bar Impact Test According to Schnadt." Abstracted from *De Ingenieur*, **50** (50), MK 15-17 (Dec. 13, 1946); *Engineers Digest*, 103 (March 1947).
6. Barr, W., and Tipper, C. F., "Brittle Fracture in Mild Steel Plates," *J.I.S.I.*, **157**, 223-238 (Oct. 1947).
7. Davidenkov, N. N., and Shevandin, E. M., *Jnl. Tech. Physics, IV*, 925 (1934) (in Russian). Also, Davidenkov, N. N., *Dynamic Metal Tests* (in Russian) 2nd ed., p. 158, *et seq.* (1936).
8. Ludwik, P., *Elements of Technological Mechanics* (in German) (1909).
9. Bagsar, A. B., "Cleavage Fracturing and Transition Temperatures of Mild Steel," THE WELDING JOURNAL, **27** (3), Research Suppl., 123-s to 131-s (1948).
10. Lilly, S. B., Carpenter, S. T., Roop, W. P., Barr, N., Kasten, E., Progress Report, "12" Flat Plate Tests, U. S. Navy, Bureau of Ships, NObs-45521, Serial No. SSC-21 (to be published).
11. Zeno, R. S., and Low, J. R., Jr., "The Effect of Variation in Notch Severity on the Transition Temperature of Ship Plate Steel in the Notched Bar Impact Test," THE WELDING JOURNAL, **27** (3), Research Suppl., 145-s to 147-s (1948).
12. Mailander, R., "The Effect of Specimen Width on Notch Toughness of Mild Steel," *Krappsche. Monatsh.*, **5**, 16–21 (1924).
13. Sauerwald, F., and Wieland, H., "The Notch Impact Test after Schuler and Moser and the Notch Toughness of Some Brasses, Copper and Aluminum at Room and Elevated Temperatures," *Z. Metallk.*, **17**, 358–363 and 392–399 (1925).
14. Kahn, N. A., and Imbembo, E. A., "A Method of Evaluating Transition from Shear to Cleavage Failure in Ship Plate and Its Correlation with Large-Scale Plate Tests," THE WELDING JOURNAL, **27** (4), Research Suppl., 169-s to 182-s (1948).

Axial Tension Impact Tests of Structural Steels*

By W. H. Bruckner† and N. M. Newmark‡

Axial tension impact tests were made on a number of project steels used in the "Wide Plate" investigation. The tests were made on notched specimens of various types. As a result of the preliminary tests a standard specimen was evolved, with a semicircular notch of 0.039 in. radius, a root diameter of 0.294 in., and an outside diameter of 0.625 in. Tests were run on these standard specimens at a number of different values of initial energy of the pendulum, obtained by varying the height of the pendulum before release. Transition temperatures were determined from both energy absorption and reduction in area, with the same results. Both curves showed sharper and more distinct transitions when the initial energy was 110 ft.-lb. or less. The results of the tests with different values of initial energy indicate approximately uniform transition temperatures for the "E" and "C" steels, but a considerable decrease in transition temperature with the lower values of initial energy for the "A" and "D" steels. The transition temperatures for the lower energies are in fair agreement with the transition temperatures determined from static tests of internally notched wide plates. The transitions for the "A" and "C" steels at 220 ft.-lb. initial energy are practically the same, but at 110 or 45 ft.-lb. there is a spread of 30 to 40° between the two steels. Although this spread is less than in the wide plate tests, it is in the right direction. In this regard, it should be noted that the ordinary Charpy test does not distinguish between these two steels. The tests are being continued to study other related properties of the steels. However, from present indications, the axial tension impact test appears to give fundamental and reliable information regarding notch sensitivity of structural steels.

Introduction

IN THE previous "Wide Plate Investigation"[1,2] a number of project steels were employed for notch-tensile static tests in which use was made of specimens which had a width of 12 to 72 in. The wide plate tests are regarded as a means for comparing the possible behavior of structural steel making up the hull plate of transport and cargo vessels. The development of small specimen tests which could be correlated with the wide plate tests has been considered as a possible criterion for the selection of steels for ship plate. Earlier attempts were made to correlate the data from Charpy V-notch and keyhole-notch flexural impact tests of the project steels with the wide plate tests.[1-3] The results of the tests indicated that there was a fair correlation with the wide plate tests in general with respect to the order of their transition temperatures but two semi-killed steels, "A" and "C," which exhibited a large difference in the wide plate tests had practically no difference in the Charpy impact tests. Moreover, the transition temperature for the wide plate tests was easily determined by the sharp decrease in energy absorption while it was difficult in general to define the transition temperature for the Charpy tests because of the gradual decrease in energy absorbed as the testing temperature decreased.

In initiating the current program of axial tension impact testing the objectives were to determine the conditions necessary for a sharp decrease of energy absorption in impact at the transition temperature, and to determine the correlation with the wide plate tests. The tests were made on the stock of some of the project steels remaining from the wide plate tests. All of the project steels are

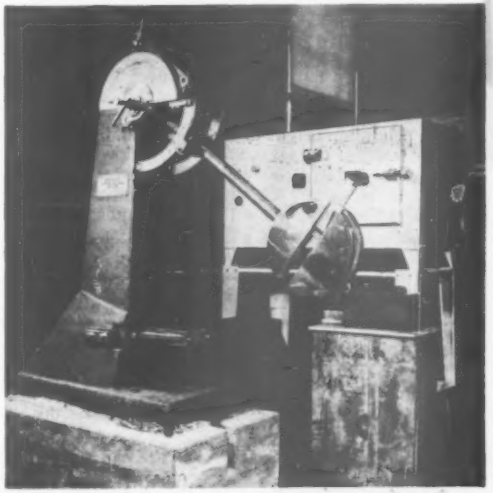
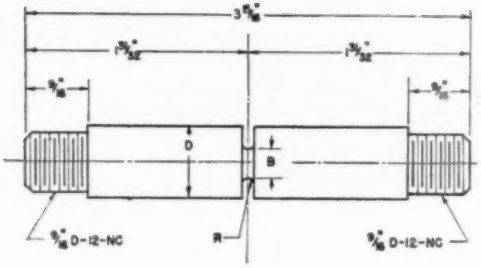


Fig. 1—Photograph of Riehle Impact Testing Machine Showing Modification for Making Tests with Less Than 110 Ft.-Lb. Initial Energy

* Presented before Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.
University of Illinois, Engineering Experiment Station, Urbana, Ill., in cooperation with the Office of Naval Research, Project N6 onr-71, Task V: Project No. NR 031-182.
† Research Assistant Professor of Metallurgical Engineering, Department of Mining and Metallurgical Engineering, University of Illinois.
‡ Research Professor of Structural Engineering, Department of Civil Engineering, University of Illinois.



DIMENSIONS OF SPECIMENS

Type of Specimen	B inches	D inches	R inches	Area at Root of Notch sq. ins.
A	0.215	0.625	0.039	0.043
B	0.294	0.625	0.039	0.069 (Standard)
C	0.352	0.625	0.039	0.097
D	0.352	0.725	0.039	0.097
E	0.294	0.588	0.039	0.069
F	0.294	0.704	0.039	0.069
G	0.294	0.704	0.046	0.069
H	0.352	0.704	0.047	0.097

Fig. 2—Design of Specimens for Axial Tension Impact Tests

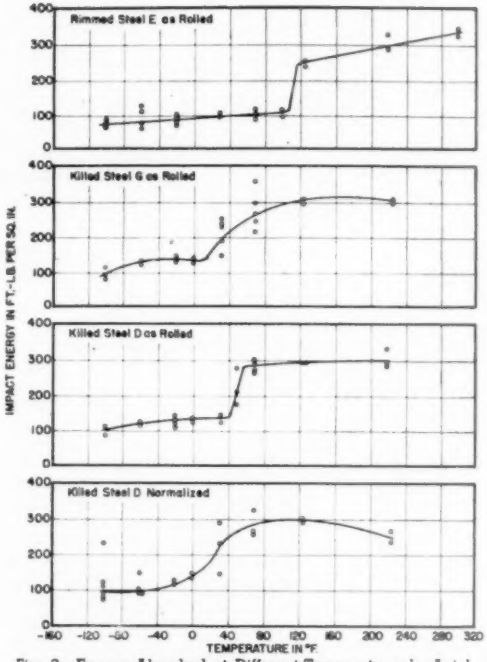

Rimmed Steel E as Rolled
Killed Steel G as Rolled
Killed Steel D as Rolled
Killed Steel D Normalized
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
TEMPERATURE IN °F
-160 -120 -80 -40 0 40 80 120 160 200 240 280 320

Fig. 3—Energy Absorbed at Different Temperatures by Axial Tension Impact Specimens, Type A, of Rimmed Steel E, As-Rolled, Killed Steel G, As-Rolled, and Killed Steel D, As-Rolled and As-Normalized

described in detail with respect to chemistry, microstructure and Charpy impact values in a paper by Klier, Wagner and Gensamer in THE WELDING JOURNAL.[4]

The axial tension notched impact test was selected because of the advantages which it had over the Charpy test; e.g., a uniaxial tensile stress and a uniform notch which could be varied to effect any desired degree of stress concentration. The first part of the program was concerned with a survey of the effects of specimen size and notch geometry upon the shape of the curve resulting from plotting the absorbed energy against the testing temperature. From the survey a standard specimen was evolved which had a semicircular notch of 0.039 in. radius, a root diameter of 0.294 in. and an outside diameter of 0.625 in. This standard specimen was employed in axial tension notch impact testing of a number of the project steels. The tests were made at various temperatures to define the change from ductile to brittle behavior. A standard Riehle impact testing machine was used. Only one pendulum was used for all the tests, the different initial energies being obtained by varying the initial height. One series of tests was carried out using a pendulum height to give 220 ft.-lb. initial energy, another series of tests was made with a lower pendulum height to give 110 ft.-lb. initial energy. The machine was modified to permit the use of initial pendulum energies in the range below 110 ft.-lb., and several series of tests were made with the pendulum in position to give initial energies of 45 ft.-lb and less.

Acknowledgment

This work has been performed as part of a cooperative research contract between the Engineering Experiment Station of the University of Illinois, of which Dean M. L. Enger is the Director, and the Office of Naval Research, under contract N6 ori-71, Task order V. All work on this task is under the supervision of Professor Newmark. The tests reported herein were performed under Professor Bruckner's direction, and the test data were compiled by him.

The authors are indebted to Dr. R. A. Hechtman, Special Research Engineer in Civil Engineering, for his services in scheduling the production of specimens for test and for many valuable suggestions. A number of

Table 1—Chemical Analyses of Project Steels in Axial Tension Impact

Steel	Kind of Steel	Treatment	Percent by Weight of Element Noted											
			C	Mn	P	S	Si	Al	Ni	Cu	Cr	Mo	Sn	N_2
A	Semi-killed	As rolled	0.26	0.50	0.012	0.039	0.03	0.012	0.02	0.03	0.03	0.006	0.003	0.004
C	Semi-killed	As rolled	0.24	0.48	0.012	0.026	0.05	0.016	0.02	0.03	0.03	0.005	0.003	0.009
Dr	Killed	As rolled	0.22	0.55	0.013	0.024	0.21	0.020	0.16	0.22	0.12	0.022	0.023	0.006
Dn	Killed	Normalized	0.19	0.54	0.011	0.024	0.19	0.019	0.15	0.22	0.12	0.021	0.025	0.006
E	Rimmed	As rolled	0.20	0.33	0.013	0.020	0.01	0.009	0.15	0.18	0.09	0.018	0.024	0.005
G	Killed	As rolled	0.20	0.86	0.020	0.020	0.19	0.045	0.15	0.15	0.04	0.018	0.012	0.006

Table 2—Series 1, Tension Impact Tests of Type A Specimens of Steels E, Dr, Dn and G; 220 Ft.-Lb. Initial Energy

Steel	Specimen No.	Testing Temperature, deg. F.	Impact Energy, ft. lb.	Impact Energy, ft. lb/in.^{2}	Approximate Percent Shear Observed on Fracture Surface
E (Rimmed)	E-7	300	15.0	344	100
	A-4	300	14.0	321	100
	E-2	220	12.0	284	97
	E-3	220	13.6	324	99
	E-4	125	10.0	231	60
	E-5	125	10.8	250	30
	E-15	100	4.0	91	0
	E-14	100	4.8	110	0
	E-8	70	4.3	99	0
	E-1	70	4.9	112	0
	A-8	70	3.7	86	0
	E-6	32	4.3	98	0
	A-5	32	4.7	92	0
	A-6	-20	3.6	83	0
	A-7	-20	3.2	77	0
	A-1	-20	3.9	89	0
	A-2	-20	2.9	67	0
	A-11	-60	3.0	69	0
	A-13	-60	5.3	120	0
	E-13	-60	4.5	103	0
	A-12	-60	2.5	59	0
	A-16	-100	3.0	70	0
	A-14	-100	3.5	79	0
	A-15	-100	3.1	69	0
Dr (Killed, as Rolled)	17-16	220	12.6	281	100
	17-17	220	14.8	330	100
	17-18	220	12.7	284	100
	17-14	125	13.3	292	92
	17-15	125	13.0	292	88
	17-19	70	12.0	269	30
	17-1	70	13.3	297	50
	17-2	70	11.7	261	30
	17-3	70	12.9	289	40
	17-20	50	12.2	275	15
	17-21	50	9.3	208	0
	17-22	50	7.8	175	0
	17-4	32	5.5	121	0
	17-5	32	6.4	143	0
	17-6	0	5.7	123	0
	17-7	0	5.6	126	0
	17-8	-20	5.7	127	0
	17-9	-20	5.9	133	0
	17-23	-20	5.6	125	0
	17-24	-20	5.2	117	0
	17-10	-60	5.1	115	0
	17-11	-60	5.4	121	0
	17-12	-100	5.0	113	0
	17-13	-100	3.8	86	0
Dn (Killed, Normalized)	11-20	225	11.3	261	100
	11-24	225	10.3	236	100
	11-22	125	13.0	300	97
	11-21	125	12.9	291	97
	11-14	70	11.4	265	70
	11-15	70	10.9	257	60
	11-9	70	13.8	324	75
	11-1	32	9.3	217	20
	11-3	32	12.2	290	10
	11-18	32	6.4	145	0
	11-6	0	5.8	135	0
	11-7	0	6.1	144	0
	11-10	-20	5.2	123	0
	11-17	-20	5.2	120	0
	11-5	-60	6.4	148	0
	11-11	-60	3.9	89	0
	11-13	-60	4.3	100	0
	11-19	-60	3.8	89	0
	11-2	-100	9.8	230	0
	11-4	-100	3.9	91	0
	11-8	-100	3.4	70	0
	11-12	-100	4.5	104	0
	11-16	-100	5.1	118	0
	11-23	-100	3.1	72	0
G (Killed)	G-6	225	13.6	303	100
	G-7	225	13.2	295	100
	G-4	125	13.0	293	97
	G-5	125	13.8	305	88
	G-1	70	16.0	355	80
	G-2	70	10.7	241	40
	G-3	70	9.6	211	20
	G-21	70	11.7	264	10
	G-22	70	13.2	292	30
	G-8	32	6.5	143	0
	G-9	32	8.3	187	0
	G-10	32	10.7	238	0
	G-23	32	10.9	245	0
	G-24	32	10.0	225	0
	G-11	0	6.1	136	0
	G-12	0	5.6	125	0
	G-13	-20	5.7	127	0
	G-14	-20	6.3	140	0
	G-15	-20	6.0	132	0
	G-16	-60	5.9	130	0
	G-17	-60	5.3	118	0
	G-18	-100	3.4	75	0
	G-19	-100	4.8	106	0
	G-20	-100	3.7	83	0

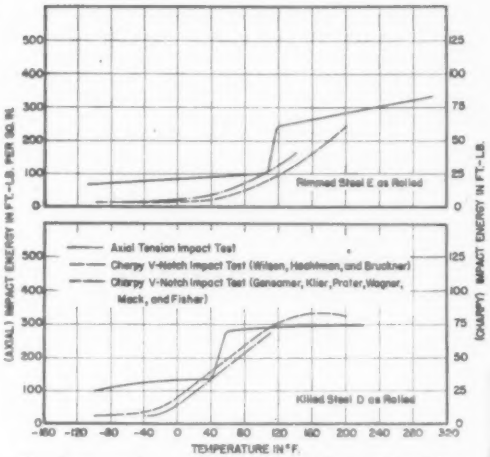

Rimmed Steel E as Rolled
Axial Tension Impact Test
Charpy V-Notch Impact Test (Wilson, Hashimoto, and Bruckner)
Charpy V-Notch Impact Test (Genaemer, Kiler, Prater, Wagner, Mack, and Fisher)
Killed Steel D as Rolled
(AXIAL) IMPACT ENERGY IN FT.-LB. PER SQ. IN.
(CHARPY) IMPACT ENERGY IN FT.-LB.
TEMPERATURE IN °F.

Fig. 4—Comparison of Energy Absorbed at Different Temperatures for Axial Tension Type A Specimens and Charpy V-Notch Specimens of Steel E and Steel D, As-Rolled

graduate assistants and undergraduate aids in the Department of Mining and Metallurgical Engineering were employed during the course of the program. These assistants were S. Paprocki, W. Jonsson, L. H. Sheep, R. L. McGaughey and E. A. Hasemeyer and their aid is gratefully acknowledged.

Methods and Materials

A standard Riehle impact testing machine was used for all of the impact tests. Calibration of the 220 ft.-lb.

Table 3—Series 2, Tension Impact Tests of Types B and C Specimens of Rimmed Steel E, Killed Steel D and G, As-Rolled, and Killed Steel D, As-Normalized. Impact Tests Only for Room Temperature, 220 Ft.-Lb. Initial Energy

Steel	Spec.	Root Diameter, in.	Impact Energy ft. lb.	Impact Energy ft. lb./in.^{2}	Percent Shear
E	R1	0.356	28.5	286	0
	R2	0.295	8.2	120	0
Dr	K1	0.353	95.4	975	40
	K2	0.294	24.7	355	15
Dn	KN1	0.353	93.6	958	70
	KN2	0.293	25.9	384	60
G	G1	0.357	105.5	1054	60
	G2	0.293	23.5	350	30

Table 4—Series 3, Tension Impact Tests of Types B, C and D Specimens of Rimmed Steel E, As-Rolled, 220 Ft.-Lb. Initial Energy

Spec. No.	Spec. Type	Testing Temp., deg. F.	Impact Energy ft. lb.	Impact Energy ft. lb/in.^{2}	Percent Shear	Percent Reduction of Area
R 5	B	180	29.0	427	100	44.0
R 7	B	125	12.3	180	—	19.3
R 6	B	79	11.9	149	0	9.8
R 8	B	0	10.0	146	0	2.9
R 12	C	180	82	833	99	44.1
R 9	C	125	77.5	794	45	36.2
R 11	C	79	27.2	280	—	15.5
R 10	C	0	9.3	95	0	2.3
R 4	D	180	63.5	647	99	35.9
R 3	D	125	68.5	698	25	31.0
R 1	D	79	19.2	195	0	8.8
R 2	D	0	10.2	104	0	2.8

initial energy level of this machine indicated a value of 221.3 ft.-lb. which was within the limit of experimental error of the calibration and satisfied the requirements of the ASTM specification E23–41T. For impact tests at energy levels of less than 110 ft.-lb. the impact testing machine was modified as illustrated in Fig. 1. The modification consisted of a pair of accurately machined quarter-sections of an annular ring rigidly bolted to the frame of the testing machine, and provided with a means of holding the pendulum in position at a height required to give the desired initial energy of the pendulum. A pendulum release mechanism was also provided in the machine modification.

The impact tests were made at specific temperatures as determined by means of a No. 34 gage copper-constantan thermocouple which was standardized against a U. S. Bureau of Standards standardized couple. The thermocouple was placed at the bottom of the notch in the specimen and brought into intimate contact with the specimen by means of a tightly wrapped lead wire. The tests below room temperature were made by immersing the assembly of the impact specimen, the tup and the screw fitting (for attaching to the pendulum), in a bath of liquid which was cooled slightly below the testing temperature. The liquid was acetone for the earlier tests and later was replaced by a noninflammable, petroleum base, solvent mixture. Dry ice, CO_2, was used to cool the liquid which was held for long periods of time at the desired temperature level by placing the container in a specially constructed insulated box.

The procedure in making the impact tests below room temperature was to cool the specimen to a previously determined temperature, the temperature being measured by means of the thermocouple attached to the specimen. The specimen assembly was held at temperature for not less than 15 min; upon removal from the refrigerant it was screwed into the pendulum of the impact machine. The specimen was broken after an elapsed time (always less than 45 sec.) which previous calibration had indicated was required to allow the specimen to heat to the desired testing temperature. The thermocouple was removed before the specimen was broken.

For the impact tests above room temperature an accurately controlled heating oven was not available until recently; therefore, each test was made with the thermocouple attached to the specimen up to just before fracture The specimen assembly was placed in a drying oven and upon reaching and holding for 15 min. a temperature of 2 to 4° above the testing temperature, it was screwed into the pendulum. The temperature of the specimen was observed to within one second or less from the time of fracture.

In general, two or more tests were made at each temperature but for the earlier survey of the effects of specimen size and shape one specimen at each temperature sufficed to show the trend. This was possible with the axial tension impact tests because the absorbed energy above and below the transition temperature is closely duplicated in multiple tests, in contrast with the general scatter of the Charpy impact tests on the same steels.

Descriptions and analyses of the project steels used for the testing program are given in Table 1. Of these steels, those designated E, Dr, Dn and G were used in the wide plate tests made at the University of Illinois; steels A and C were used in the wide plate tests made at the University of California. All of the impact specimens were machined from $^3/_4$-in. thick plates of the various steels.

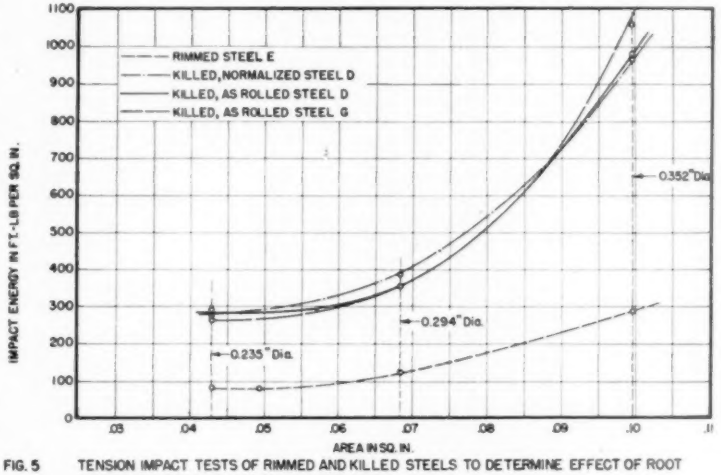


FIG. 5 TENSION IMPACT TESTS OF RIMMED AND KILLED STEELS TO DETERMINE EFFECT OF ROOT DIAMETER ON TESTS AT ROOM TEMPERATURE.

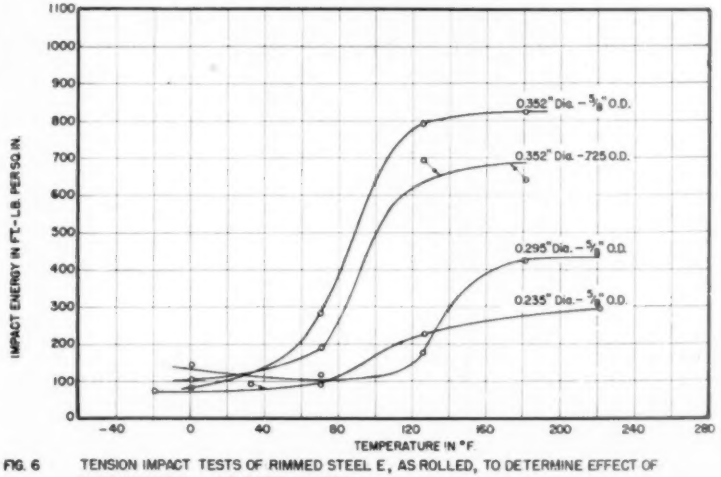


FIG. 6 TENSION IMPACT TESTS OF RIMMED STEEL E, AS ROLLED, TO DETERMINE EFFECT OF ROOT DIAMETER AND OUTER DIAMETER.

The basic design of the cylindrical specimen used is shown in Fig. 2, and the variations in the critical dimensions are given below the figure for all the tests which were made.

Table 5—Series 4, Tension Impact Tests of Types E,F,G and H Specimens of Rimmed Steel E, As-Rolled, 220 Ft.-Lb. Initial Energy

Spec. Type	Spec. No.	Testing Temp., deg. F.	Impact Energy, ft. lb.	Impact Energy, ft. lb/in.^{2}	Percent Shear	Percent Reduction of Area
E	53	220	30	437	100	39.0
	9	220	33	480	100	42.2
	10	170	29.9	435	60	33.7
	12	170	34.5	498	60	37.0
	78	160	24.3	354	20	31.0
	59	160	27.6	402	20	31.6
	14	150	20.0	291	20	25.2
	40	150	21.0	304	20	—
	35	150	28.5	406	30	33.9
	6	140	23.9	346	20	30.2
	17	140	20.2	294	15	16.6
	11	140	16.9	244	5	20.4
	72	130	17.2	251	10	27.8
	48	130	13.1	185	10	12.9
	58	120	10.9	154	0	12.3
	2	120	14.9	215	0	14.8
	19	110	8.7	127	0	6.7
	20	110	11.0	160	0	8.6
	26	90	8.6	121	0	7.6
	7	90	10.2	149	0	7.6
	4	32	8.2	119	0	6.0
	15	32	6.8	98.5	0	4.5
	42	-20	7.3	105	0	3.7
	60	-20	5.3	76.5	0	0
F	51	250	28.0	404	99	38.5
	52	250	27.2	391	100	37.3
	49	219.2	27.9	403	96	37.9
	48	200	35.0	509	97	34.3
	50	200	27.2	390	97	37.3
	32	200	25.8	384	100	33.0
	33	170	21.0	312	85	28.3
	34	170	23.7	352	95	32.4
	35	150	25.0	368	95	41.4
	44	150	19.1	267	10	18.3
	45	150	20.6	300	10	23.9
	53	130	15.8	228	10	16.7
	54	130	14.5	211	10	13.1
	46	110	11.0	155	0	8.6
	47	110	9.5	137	0	7.4
	38	72	9.1	133	0	6.0
	42	72	5.4	80	0	4.0
	43	72	8.2	122	0	8.7
	40	36	8.0	118	0	3.2
	39	32	8.6	127	0	4.7
	41	32	7.7	113	0	4.1
	36	0	5.9	86.9	0	1.3
	37	0	9.0	133	0	2.1
G	31	220	29.8	442	100	—
	36	220	26.8	392	100	36.5
	37	190	26.0	381	95	34.7
	22	190	34.2	493	95	35.8
	16	180	21.0	320	98	33.4
	25	180	21.5	318	99	28.2
	23	180	22.0	336	99	32.0
	41	170	23.0	344	95	35.8
	34	170	21.1	320	30	—
	21	160	17.1	266	15	23.0
	8	160	21.9	328	80	31.0
	18	150	24.0	359	25	28.2
	38	150	13.4	198	2	12.5
	33	150	16.3	240	2	18.0
	30	150	18.8	283	20	26.8
	43	140	8.9	132	0	7.3
	5	140	11.2	166	0	15.0
	47	130	8.3	127	5	8.8
	1	130	8.8	129	1	7.3
	32	82	7.7	114	0	0.6
	40	82	8.8	133	0	3.8
H	56	220	68.0	698	100	36.3
	26	220	60.0	615	98	39.2
	24	170	65.0	667	80	36.5
	57	170	57.5	590	80	39.4
	69	160	54.1	576	90	33.5
	27	150	55.3	568	60	37.2
	54	130	57.8	591	50	32.5
	50	130	64.8	655	10	—
	66	130	34.8	357	10	16.8
	67	130	58.6	600	20	31.5
	75	130	40.3	413	10	24.5
	71	120	32.6	334	5	14.5
	52	120	34.6	355	5	18.9
	62	110	30.5	313	10	15.3
	65	110	17.9	184	0	7.8
	73	110	21.2	218	0	10.7
	76	110	33.6	345	10	10.5
	75	110	20.9	214	10	19.9
	55	90	16.5	168	0	5.6
	74	90	17.7	182	0	16.8
	31	32	16.3	167	0	5.3
	64	32	16.2	166	0	—
	70	-20	10.4	107	0	0.9
	77	-20	9.4	97	0	0.0

Results of Tests

Tension impact tests were first made with specimens of type A, Fig. 2, machined from steels E, Dr, Dn and G. The tests were made with an initial energy of 220 ft.-lb. in the pendulum and are designated as Series 1. The data for these tests are given in Table 2, and the cor-

Table 6—Series 5, Tension Impact Tests of Type B Specimens of Rimmed Steel E, As-Rolled. Tests Made with Initial Energies of 220, 110, 45, 33.8 and 22.5 Ft.-Lb.

Initial Energy, ft. lb.	Spec. No.	Testing Temp., deg. F.	Impact Energy, ft. lb.	Impact Energy, ft. lb/in.^{2}	Percent Shear	Percent Reduction of Area
220	22	220	29.7	420	100	43.3
	23	220	34.0	462	100	45.8
	27	160	27.2	372	80	36.0
	20	127	22.7	310	10	28.5
	21	127	16.2	220	10	21.5
	26	128	17.9	257	10	26.2
	31	100	13.7	187	0	14.0
	32	100	15.8	215	0	13.2
	1	81	10.9	156	0	7.8
	2	81	10.9	153	0	7.7
	5	0	6.4	88	0	7.8
	6	0	6.1	83	0	2.6
	11	-40	8.0	111	0	5.2
	12	-40	8.3	103	0	6.9
	13	-100	5.7	82	0	7.9
	14	-100	6.1	84	0	5.3
	15	-100	6.1	84	0	1.3
110	24	220	34.6	473	100	41.7
	25	220	24.5	470	100	34.8
	28	160	30.9	422	90	34.2
	18	127	22.9	329	25	29.6
	19	127	26.3	377	50	34.0
	29	100	8.4	114	0	13.9
	30	100	12.4	180	0	10.5
	3	81	11.4	160	0	7.4
	7	0	4.5	63	0	6.4
	8	0	7.7	103	0	4.4
	9	-40	6.6	91	0	7.7
	10	-40	8.0	111	0	5.9
	16	-100	3.6	49	0	10.1
	17	-100	3.6	52	0	3.3
45	A34	220	32.4	456	100	36.0
	A32	220	32.1	463	100	36.4
	A13	180	32.9	468	97	35.7
	A23	180	34.3	482	97	36.3
	A16	140	30.1	428	50	33.4
	A44	140	29.2	416	50	30.0
	A40	125	29.0	413	35	30.6
	A19	125	18.7	267	0	17.8
	A 6	110	17.0	240	7	17.8
	A 2	110	18.6	264	10	18.4
	A26	90	11.5	164	0	9.8
	A 7	90	13.3	192	0	11.0
	A 4	70	9.8	137	0	9.1
	A37	70	9.3	131	0	8.6
	A43	32	8.5	121	0	4.6
	A29	32	8.4	120	0	5.8
	A24	0	10.1	143	0	4.2
	A28	0	10.0	140	0	5.9
	A 5	-40	4.5	64.5	0	.6
	A25	-40	8.1	115	0	2.0
33.8	A17	140	31.7	452	96	36.6
	A 1	140	31.2	448	98	32.9
	A48	120	31.9	454	60	31.5
	A20	120	29.7	420	50	30.0
	A50	115	15.9	228	3	16.7
	A49	110	15.2	217	10	15.7
	A27	110	29.8	430	70	26.3
	A11	110	27.0	385	20	28.5
	A 3	105	14.0	201	2	14.2
	A 8	100	12.7	182	3	12.9
	A41	100	13.7	195	3	13.0
	A10	90	10.8	155	0	9.6
	A47	90	13.0	187	0	10.3
22.5	A31	220	*I.E.	323+	—	18.5
	A18	220	*I.E.	323+	—	18.5
	A36	110	*I.E.	318+	—	17.8
	A33	110	*I.E.	321+	—	15.4
	A15	100	*I.E.	318+	—	17.8
	A21	100	*I.E.	316+	—	16.6
	A35	95	19.5	278	1	17.8
	A38	95	12.1	170	1	17.8
	A 9	90	11.1	157	0	11.0
	A39	90	12.1	170	0	12.2
	A42	76	9.7	140	0	7.4
	A22	76	12.4	174	0	10.4
	A12	0	9.7	138	0	3.3
	A45	0	9.3	134	0	2.9
	A14	-40	8.3	118	0	2.0
	A30	-40	7.2	101	0	2.7

*Specimens did not break—energy absorption was considered to be at least the amount of initial energy (I.E.) in the pendulum. Reduction of area was determined for the unbroken specimens.

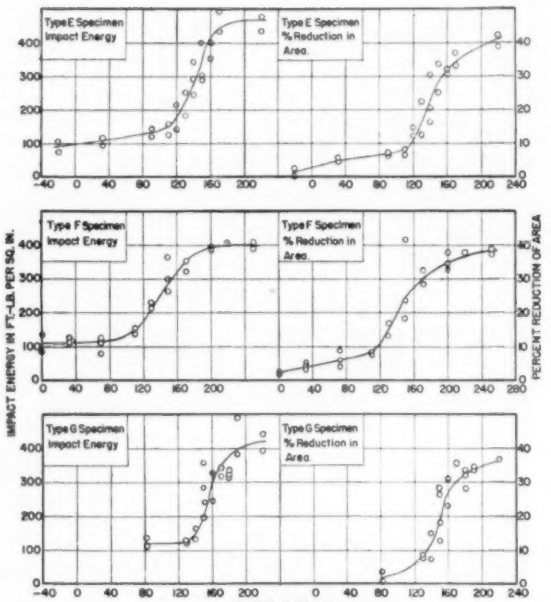

Type E Specimen Impact Energy
Type E Specimen % Reduction in Area.
Type F Specimen Impact Energy
Type F Specimen % Reduction in Area.
Type G Specimen Impact Energy
Type G Specimen % Reduction in Area.
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION OF AREA
TEMPERATURE IN °F.

FIG. 7 TENSION IMPACT TESTS AND PERCENT REDUCTION OF AREA OF TYPE E, F, AND G SPECIMENS OF RIMMED STEEL E AS ROLLED.

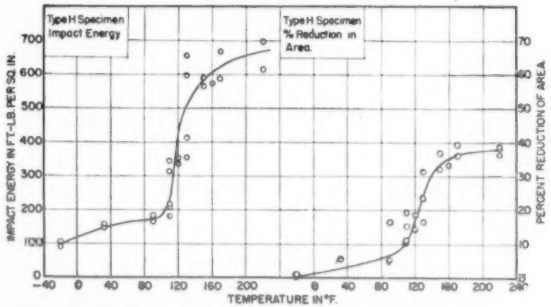

Type H Specimen Impact Energy
Type H Specimen % Reduction in Area.
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION OF AREA
TEMPERATURE IN °F.

FIG. 8 TENSION IMPACT TESTS AND PERCENT REDUCTION OF AREA OF TYPE H SPECIMENS OF RIMMED STEEL E AS ROLLED.

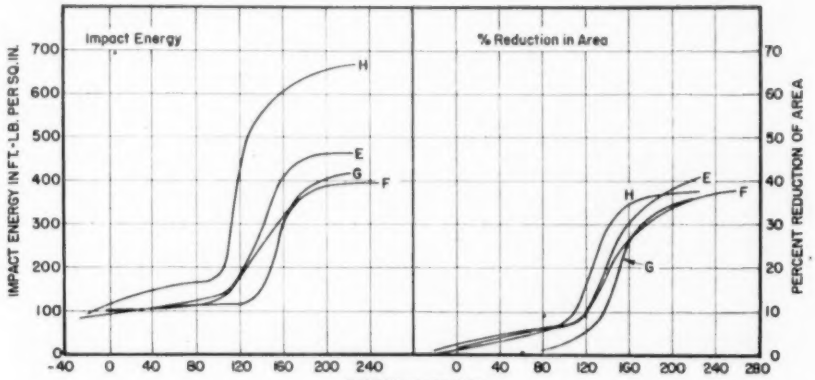


Fig. 9—Comparison of Tension Impact Tests of Types E, F, G and H Specimens of Rimmed Steel E, As-Rolled

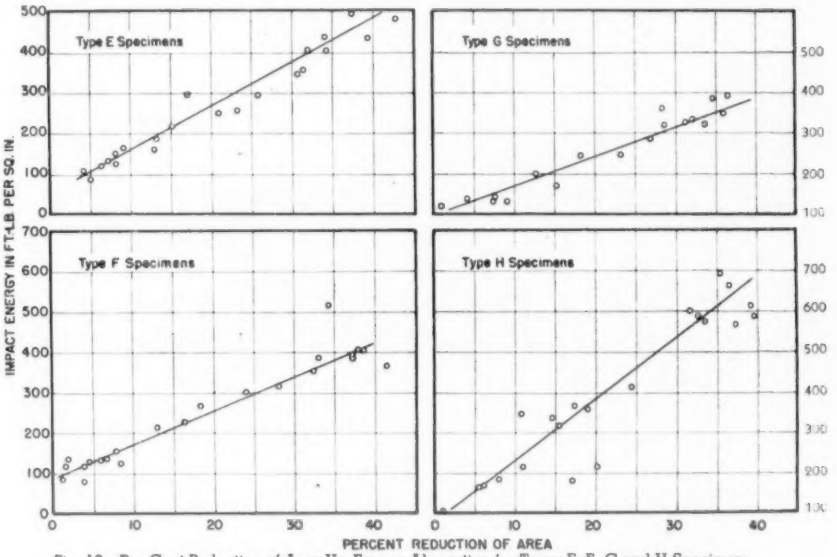


Fig. 10—Per Cent Reduction of Area Vs. Energy Absorption for Types E, F, G and H Specimens

responding impact energy-temperature curves are given in Fig. 3. The impact energy, in foot-pound per square inch of specimen area at the root of the notch, was obtained by dividing the energy absorbed in the specimen by the original root area as determined from measurements of the root diameter. The latter was determined for each specimen by use of a microscope and a measuring device which could be read to 0.0005 in. or better.

Figure 4 gives a comparison of the Series 1 tension impact tests and the Charpy V-notch tests for two of the steels, E and Dr. It is apparent that the transition is more clearly defined by the axial impact test than by the Charpy test.

The next series of tests, designated as Series 2, was made with specimens of types B and C, Fig. 2, machined from the same steels E, Dr, Dn and G. The tests were made only at room temperature (72° F.) to survey the rate of increase in energy absorption with increase in

Table 7—Series 6, Tension Impact Tests of Type B Specimens of Semikilled Steel A, As-Rolled. Tests Made with Initial Energies of 220, 110 and 45 Ft.-Lb.

Initial Energy, ft. lb.	Specimen Number	Testing Temp., Deg. F.	Impact Energy ft. lb.	Impact Energy ft. lb./in.²	Per cent Shear	Per cent Reduction of Area
220	7	220	29.8	433	100	39.7
	12	220	29.2	418	100	37.3
	3	180	30.2	436	100	41.2
	6	180	28.7	412	100	39.3
	4	140	27.9	398	95	36.7
	5	140	27.9	402	100	37.0
	10	125	26.3	372	90	35.5
	15	125	28.0	407	80	36.5
	19	125	25.8	270	60	32.4
	2	110	25.3	361	20	31.2
	13	110	24.8	351	20	32.8
	16	110	16.0	231	20	21.1
	20	110	23.3	334	60	30.7
	21	110	19.9	287	10	22.2
	22	110	21.8	313	10	27.9
	23	90	11.9	171	0	12.3
	26	90	15.7	228	0	17.5
	25	90	10.8	154	1	10.4
	1	75	11.2	162	0	11.8
	14	75	10.1	145	0	9.6
	8	0	7.2	102	0	4.0
	9	0	7.8	110	0	4.0
	18	-40	5.3	77	0	1.4
	24	-40	5.2	74	0	2.0
110	B16	220	29.7	438	100	38.3
	B26	220	30.5	446	100	37.6
	B23	180	36.1	525	100	37.5
	B19	180	28.2	422	100	38.5
	B27	140	28.7	426	99	36.8
	B18	140	27.8	412	99	36.8
	B 5	110	23.0	337	30	28.8
	B14	110	24.7	364	60	32.3
	B 7	90	20.0	293	20	28.2
	B21	90	24.1	352	20	28.2
	B 4	74	13.8	202	0	14.5
	B 2	74	10.6	149	0	12.4
	B 3	60	8.6	126	0	8.6
	B 6	60	8.3	121	5	8.0
	B 1	32	4.7	69	0	4.1
	B15	32	8.6	123	0	6.8
	B13	32	8.0	117	0	5.3
	B11	0	2.5	37	0	2.6
	B12	0	6.9	103	0	3.4
	B24	0	5.5	80	0	4.7
45	F 5A	140	30.1	442	99	33.4
	F 6A	140	30.3	445	99	33.0
	F 3A	100	28.5	421	97	32.6
	F 4A	100	26.1	386	85	29.8
	F16A	80	25.8	381	10	28.0
	F15A	80	21.2	312	5	23.0
	F17A	80	19.8	292	5	20.1
	F 1A	79.5	23.2	340	99	15.5
	F 2A	79.5	17.2	254	2	16.4
	F23A	77	27.8	406	10	27.6
	F18A	70	17.2	252	2	17.2
	F24A	70	15.6	230	1	15.0
	F19A	70	15.1	222	2	14.4
	F23A	70	15.0	221	1	13.1
	B22A	60	18.5	271	2	4.1
	F 7A	60	15.6	230	2	11.3
	F20A	60	15.2	224	1	15.0
	B20A	60	13.8	203	1	11.2
	F 8A	60	11.9	175	2	7.95
	F 9A	50	13.6	202	1	11.0
	F21A	50	13.4	197	1	10.9
	F10A	50	12.6	185	1	9.23
	B10A	50	12.8	185	0	10.5
	F22A	40	13.1	194	0	9.55
	B 8A	40	11.7	171	0	10.7
	F25A	40	11.1	164	0	6.49
	B 9A	40	8.8	129	0	6.1
	F11A	20	12.2	180	0	5.46
	F12A	20	11.6	170	0	6.76
	F13A	-20	10.2*	149	0	3.06
	F14A	-20	8.8	131	0	3.42

Table 8—Series 6, Tension Impact Tests of Type B Specimens of Semikilled Steel C, As-Rolled. Tests Made with Initial Energies of 220, 110 and 45 Ft.-Lb.

Initial Energy, ft. lb.	Specimen Number	Testing Temp., deg. F.	Impact Energy ft. lb.	Impact Energy ft. lb./in.²	Per cent Shear	Per cent Reduction of Area
220	7C	220	26.0	371	95	28.9
	8C	220	25.9	374	95	30.3
	5C	180	23.7	342	70	29.7
	6C	180	23.8	349	70	29.7
	18C	180	25.8	375	80	28.6
	14C	160	24.8	358	40	25.7
	19C	160	26.3	377	90	29.6
	1C	140	27.9	402	20	28.0
	22C	140	21.9	315	15	26.7
	9C	125	19.3	281	15	23.5
	15C	125	21.2	306	15	24.0
	16C	125	20.2	292	10	23.4
	11C	110	11.9	172	2	10.5
	12C	110	12.8	185	3	12.4
	13C	110	19.2	277	10	21.1
	26C	110	16.2	232	10	17.3
	4C	90	21.1	305	10	25.1
	23C	90	10.0	144	0	9.2
	24C	90	10.4	150	0	8.7
	17C	90	19.9	289	2	12.5
	2C	75	8.7	125	0	6.0
	3C	75	10.1	149	0	8.0
	20C	0	7.7	111	0	2.7
	21C	0	9.2	132	0	3.9
	10C	-40	7.7	113	0	1.9
	25C	-40	6.8	99.4	0	1.2
110	D 9C	220	24.6	355	99	31.4
	D21C	220	22.9	340	99	27.1
	D17C	180	21.0	308	75	28.1
	D 6C	180	23.5	339	80	28.5
	D22C	140	19.9	295	20	26.0
	D12C	140	21.4	313	20	24.6
	D24C	125	17.4	251	15	21.7
	D15C	125	21.8	317	15	24.2
	D 5C	110	14.3	207	2	17.0
	D14C	110	13.5	198	2	14.3
	D25C	100	11.6	169	5	13.6
	D 4C	100	7.5	110	2	8.9
	D20C	90	10.0	146	1	12.4
	D10C	90	7.5	108	0	9.8
	D 8C	70	7.0	102	0	6.0
	D13C	70	8.0	117	0	6.6
	D11C	32	6.8	99.5	0	5.3
	D 2C	32	6.8	98.6	0	5.7
	D18C	0	5.3	73	0	2.9
	D 3C	0	6.0	88	0	3.2
45	E10C	180	34.2	505	96	35.5
	E 9C	180	34.0	499	99	36.9
	E 5C	140	34.2	499	65	35.1
	E 6C	140	32.7	480	60	33.6
	E22C	125	30.2	444	55	33.0
	E23C	125	26.2	384	10	24.6
	E 3C	110	31.1	457	20	29.7
	E18C	110	30.2	443	10	30.8
	E20C	110	28.8	421	5	31.0
	D 1C	110	23.3	339	15	26.9
	E 4C	110	17.5	258	2	16.9
	E21C	110	16.6	245	2	15.6
	E19C	110			5	26.8
	D16C	100	21.3	312	10	22.2
	E25C	100	18.9	280	2	17.6
	E17C	100	17.8	262	2	17.5
	D26C	100	15.4	227	10	21.1
	E24C	100	13.9	202	1	12.6
	D19C	95	14.7	214	5	17.4
	D 7C	95	13.2	190	0	14.2
	E 8C	90	16.1	236	0	9.23
	D23C	90	13.6	199	0	14.7
	E 7C	90	11.3	166	0	12.2
	E 2C	81	13.5	199	0	8.7
	E 1C	80	14.8	217	0	10.9
	E16C	79	12.7	188	2	9.0
	E12C	32	10.4	153	0	5.75
	E11C	32	8.8	121	0	6.47
	E13C	0	12.4	183	0	4.81
	E15C	0	9.1	134	0	3.39
	E14C	0	5.9	86.4	0	1.47

specimen area under the notch. The tests were made with an initial energy of 220 ft.-lb. The data from the tests are given in Table 3, and a comparison of the absorbed energy per unit of area of cross section for specimens of types A, B and C is shown in Fig. 5. It should be noted that room temperature (72° F.) is below the transition temperature of steel E and is above the transition temperature of the other steels.

The energy absorption of the specimens with the larger root diameters was greater than that for the Type A specimens, and since the impact energies of the types B and C specimens were a greater proportion of the capacity of the machine, it was felt the energies for these specimens could be more accurately measured than for the Type A specimens.

Several series of tests were made using an initial energy of 220 ft.-lb. with specimens of only one steel, E as-rolled, having notch diameters of either 0.294 or 0.352 in. The specimens of one series, designated Series 3, were of the types B, C and D. The purpose in testing this series was to determine the effect on the transition temperature of the root diameter, and to determine with the largest root diameter of 0.352 in. the effects of increasing the outside diameter to the maximum obtainable from the $^3/_4$-in. thick plate from which the specimens were machined. Only one specimen was tested at each temperature. The data for this series are given in Table 4. It will be noted that the per cent reduction of area is given in the last column of the table. The reduction of area was determined from the original area and the fracture area determined from measurements of root diameter under the microscope. The impact data given in Table 4 are also given in the curves of Fig. 6. The impact energy-temperature curve for the smaller specimens (Type A) is also included in Fig. 6 for purposes of comparison.

The other series of tests, designated as Series 4, was made with the larger specimens of types E, F, G and H, Fig. 2. In this series, each critical dimension, the outer diameter, notch diameter and notch radius, were varied separately: thus types E and F differed only in external diameter, F and G only in radius at root of notch and G and H essentially only in root diameter. Also, specimen types E and H were completely similar geometrically.

A large number of specimens were tested in order to define the transition temperature accurately. The data for the impact tests made with this series of specimens are given in Table 5. Figures 7 and 8 give the impact energy-temperature curves for the data in Table 5. All four curves of Figs. 7 and 8 are compared with each other in Fig. 9. A plot of the per cent reduction of area vs. the energy absorption for the four types of specimens tested in tension impact in the Series 4 tests is shown in Fig. 10. The relation is approximately linear, but there is a fair amount of scatter.

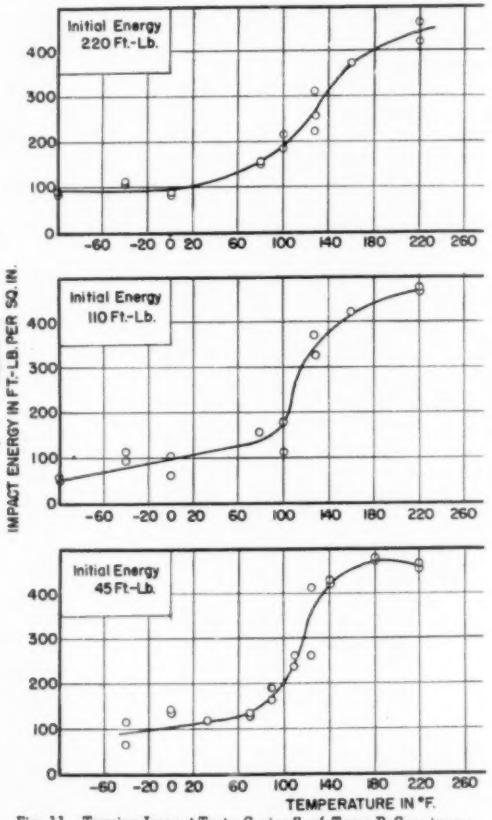


Fig. 11—Tension Impact Tests, Series 5, of Type B Specimens of Rimmed Steel E, As-Rolled; 220, 110 and 45 Ft.-Lb. Initial Energy

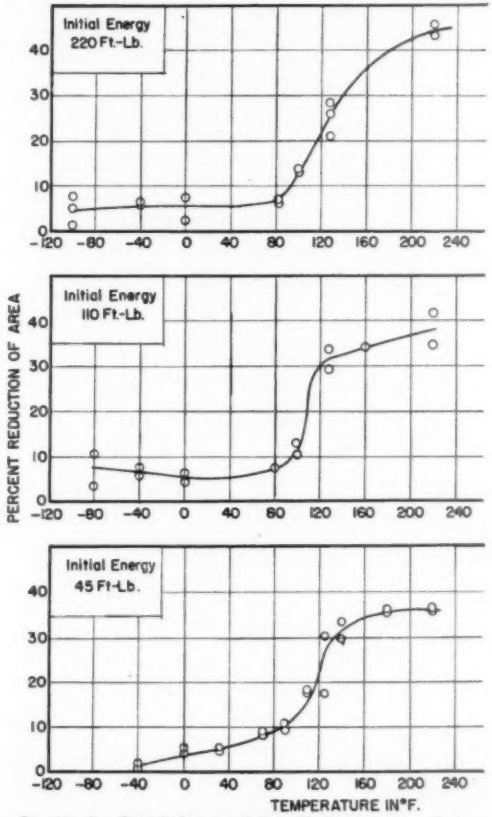


Fig. 12—Per Cent Reduction of Area Vs. Temperature, Series 5, Type B Specimens of Rimmed Steel E, As-Rolled; 220, 110 and 45 Ft.-Lb. Initial Energy

The data obtained from the four series of tension impact tests indicated that specimens of type B would be most suitable for a comparison standard in determining the transition temperature of the project steels. All subsequent tension impact tests were therefore made with the selected standard, Type B specimens.

The next series of tests, Series 5, was made on specimens machined from the rimmed steel E as-rolled. Complete tests were made to determine the transition temperature for five different initial pendulum energies of 220, 110, 45, 33.8 and 22.5 ft.-lb. The data are given in Table 6. The impact energy-temperature curves corresponding to the data in Table 6 are given in Figs. 11, 12 and 13.

The next series of tests, Series 6, was made with standard Type B specimens machined from the semikilled steels A and C. The transitions for these steels were not separated in the Charpy impact tests previously made, although the wide plate tests clearly indicated the superiority of steel A since it had a considerably lower transition temperature than steel C. A large number of specimens were tested at each temperature, with initial energies of 220, 110 and 45 ft.-lb. Tables 7 and 8, and Figs. 14 and 15 summarize the data for the Series 6 tests.

A final series of tests, Series 7, was made with standard Type B specimens machined from the killed, as-rolled, steel Dr and the killed, normalized steel Dn. A large number of specimens was tested at each temperature, with initial energies of 220, 110 and 45 ft.-lb. The data for this series of tests are given in Tables 9 and 10 and the curves of impact energy vs. temperature corresponding to the data are given in Figs. 16 and 17.

Discussion of Test Data

General

In addition to the plots of absorbed energy and of reduction in area vs. temperature, an attempt was made to analyze the data by plotting impact energy per unit of area at the root of the notch after fracture vs. temperature. Although these fracture area-impact energy curves gave substantially the same trend of results as the other plots, there appeared to be somewhat less scatter in the transition range for these plots. As an illustration, fracture area-impact energy curves for steels A and C are given in Figs. 18 and 19, respectively. These are given primarily because of the interest in these two steels, and for completeness in presenting the data concerning them. The fracture area -impact energy curves for the other steels had the same general appearance.

A summary of transition temperatures determined by various means from the test data is given in Table 11. Values are given for transition temperature obtained from absorbed energy, reduction of area and from the impact energy per unit of fracture area. In addition, the temperature corresponding to a 15% reduction in area at the root of the notch is listed. The tabulated transition temperatures are subject to some uncertainties and are estimated only to the nearest 5°. Differences in transition temperature of 10° or less are not regarded as significant in these data.

For comparison, values are given in Table 12 of transition temperatures for the same steels as determined by Charpy V-notch and by keyhole-notch flexural impact tests (from Table 8 of the paper by Klier, Wagner, and Gensamer[4]), and as determined by the wide plate tests at Illinois and California.

Series 1

The results of the Series 1 tension impact tests of Type A specimens of the three killed steels and one rimmed steel show that there is a well-defined transition temperature for the steels E and Dr. For the steels Dn and G the drop in the impact energy-temperature curve is not sharp and definite. However, the maximum energy absorption just above room temperature for the

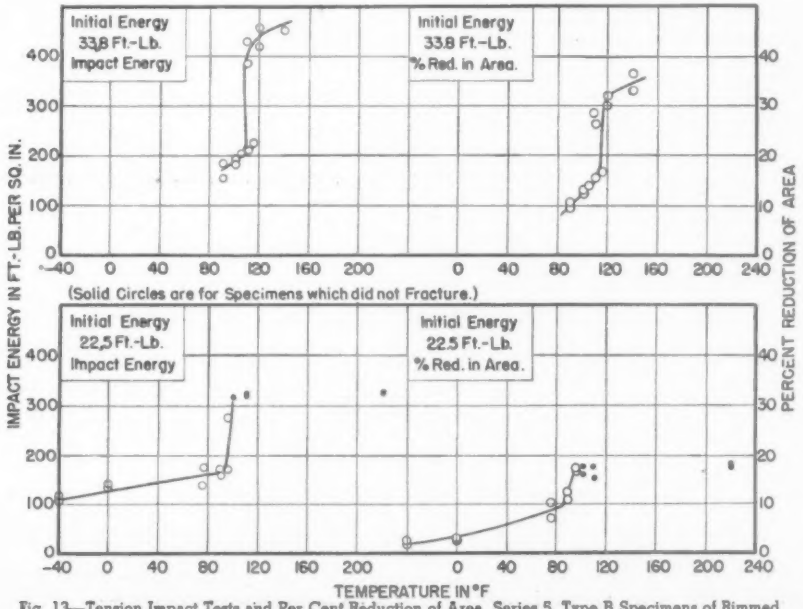


Fig. 13—Tension Impact Tests and Per Cent Reduction of Area, Series 5, Type B Specimens of Rimmed Steel E, As-Rolled; 33.8 and 22.5 Ft.-Lb. Initial Energy

Type A specimens was only about 15 ft.-lb. which is less than 10% of the capacity of the impact-testing machine at the 220 ft.-lb. initial energy level. The Type A specimens were quite delicate to handle during impact testing and great care was required to avoid plastic deformation in the test section prior to testing. There was also the possibility of an error in testing the Type A specimens in impact due to the bending moment produced in the notch area by the heavy tup while the pendulum was in motion. These considerations dictated the use of specimens of larger cross-sectional area. However, the geometrical proportions of the axial impact specimens in Series 1 appeared to be about right since the transition temperatures were within about 20° F. of the transitions determined from the wide plate tests.

Series 2

The objective of this series was to determine a root diameter of the notch to give a greater energy absorption than for the Type A specimens, yet not so great as to prevent using the testing machine at several initial energy levels. It was apparent that the Type C specimens, which absorbed nearly 100 ft.-lb. in the ductile range, were too large, whereas the Type B specimens with about twice the energy absorption of the Type A specimens would require only about 25 ft.-lb. for fracture in the ductile range. The decision was therefore made to standardize on the root diameter of 0.294 in. for the major part of the work. The radius of notch and the outer diameter remained to be investigated.

Series 3 and 4

The results of the Series 3 tests are less dependable than those of the other Series since so few specimens were tested. This series and series 4 were intended to arrive at the outline of notch to give the most consistent results with as close a correlation to the wide plate tests as possible. The Series 3 tests indicated roughly that with larger root diameter the transition is lower, and for a given root diameter the effect of an increase in external diameter is to raise the transition. These effects are consistent with the changes in stress concentration at the notch.

The results of the Series 4 tension impact tests indicate as in Series 3 the effects of increasing the root diameter of the tension impact specimens from 0.294 to 0.352 in. The other dimensions, outer diameter and notch radius, of the type E and H specimens are related to each other in the same ratio of 294/352, thus making the E and H specimen types geometrically similar. The specimens of type F and G were included to determine the cumulative effects of the changes made in the Type E specimen to arrive at Type H as the end product. The results given in Table 11 show that the transition temperatures for types E, F and G specimens increase in this order although the increase is slight. The increase in the transition temperature of Type F compared with Type E is a logical one and is to be expected because of the increased concentration of stress resulting from the larger

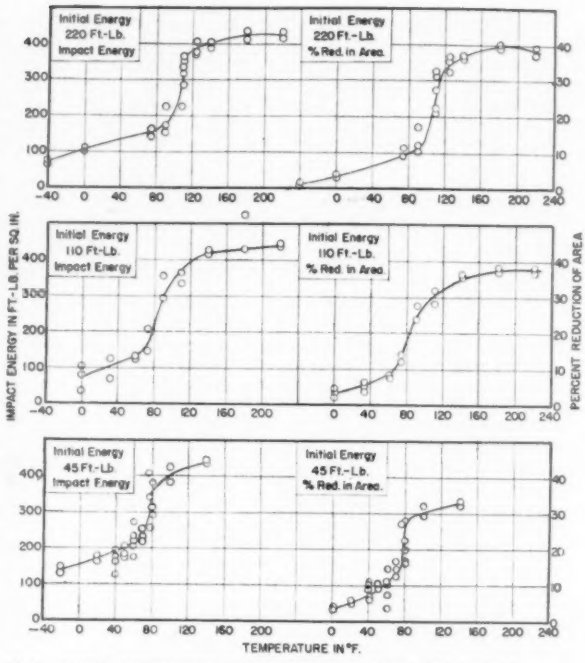

Initial Energy 220 Ft.-Lb. Impact Energy
Initial Energy 220 Ft.-Lb. % Red. in Area
Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION OF AREA
TEMPERATURE IN °F.

FIG. 14 TENSION IMPACT TESTS AND PERCENT REDUCTION OF AREA, SERIES 6, TYPE B SPECIMENS OF SEMI KILLED STEEL A AS ROLLED; 220, 110, AND 45 FT.-LB. INITIAL ENERGY

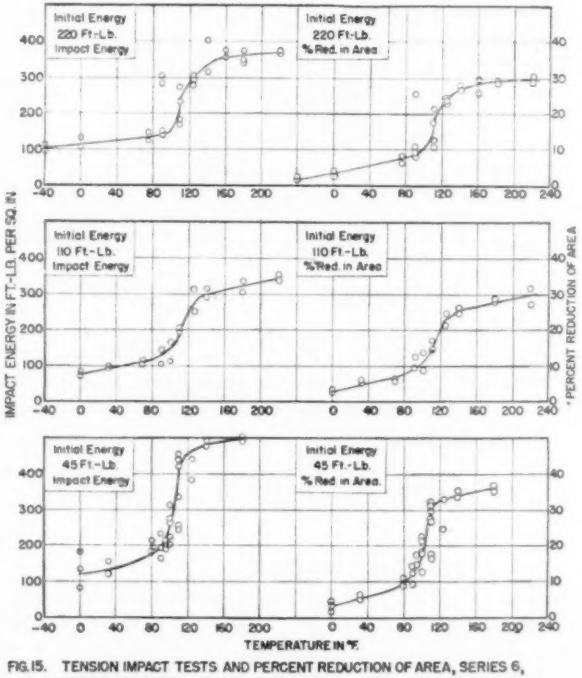

Initial Energy 220 Ft.-Lb. Impact Energy
Initial Energy 220 Ft.-Lb. % Red. in Area
Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION OF AREA
TEMPERATURE IN °F.

FIG. 15. TENSION IMPACT TESTS AND PERCENT REDUCTION OF AREA, SERIES 6, TYPE B SPECIMENS OF SEMI KILLED STEEL C AS ROLLED; 220, 110, AND 45 FT.-LB. INITIAL ENERGY.

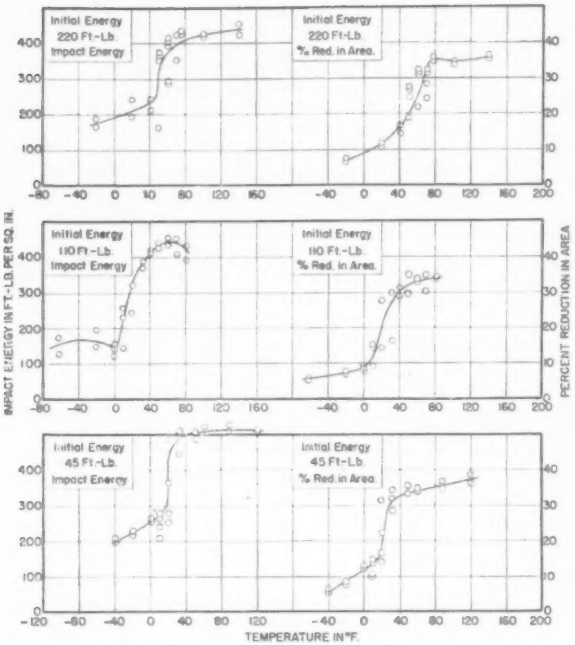

Initial Energy 220 Ft.-Lb. Impact Energy
Initial Energy 220 Ft.-Lb. % Red. in Area
Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION IN AREA
TEMPERATURE IN °F.

FIG. 16 TENSION IMPACT TESTS AND PERCENT REDUCTION OF AREA, SERIES 7, TYPE B SPECIMENS OF KILLED STEEL D_f AS ROLLED; 220, 110, AND 45 FT.-LB. INITIAL ENERGY.

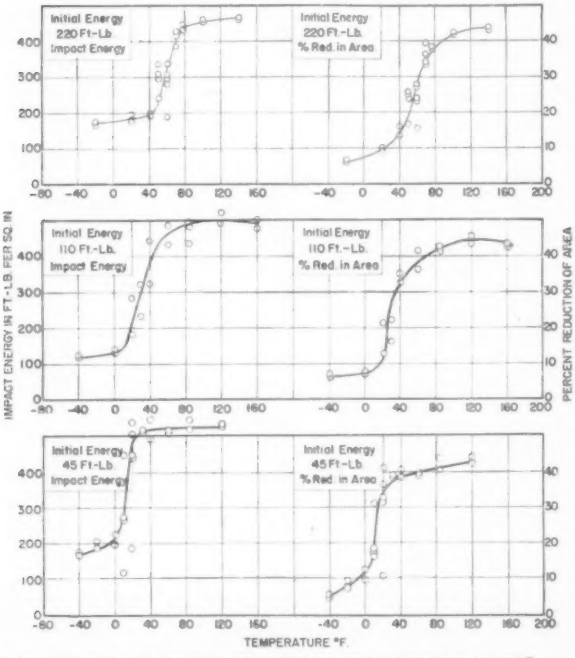

Initial Energy 220 Ft.-Lb. Impact Energy
Initial Energy 220 Ft.-Lb. % Red. in Area
Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION OF AREA
TEMPERATURE °F.

FIG. 17 TENSION IMPACT TESTS AND PERCENT REDUCTION OF AREA, SERIES 7, TYPE B SPECIMENS OF KILLED STEEL D_n AS NORMALIZED; 220, 110, AND 45 FT.-LB. INITIAL ENERGY.

outer diameter. The second result, an increase in the transition temperature of Type G specimens with the larger root radius is entirely unexpected and may be due to the less definite indication of a transition range. For the specimens of Type G the impact-temperature curve showed a more gradual decrease in energy absorption with decrease in temperature as contrasted with the sharp transition range of the other types of specimens.

The type E and H specimens, which were geometrically similar in shape, had about the same transition. This is not unexpected since the change in size is small, and the size effect may not be important in this range.

As a result of these studies it was decided to standardize on the Type B specimens for further tests.

Series 5, 6 and 7

These tests constitute the major part of the paper. All tests were made on specimens of Type B, and several different initial energy levels (220, 110, and 45 ft.-lb., generally) were used for each steel.

The general trend of the various curves of impact energy vs. temperature is the same. There is more scatter, particularly in the vicinity of the transition range, for tests with an initial energy of 220 ft.-lb. than for the lower values. In the ductile range or in the brittle range, away from the transition zone, the energy absorption in the specimen is apparently independent of the initial energy of the pendulum. This is not true for very low values of initial energy compared with the energy required to rupture the specimen. There is a tendency for a greater apparent absorption of energy when the specimen is given barely enough energy to cause failure. This is shown, for example, in Fig. 15, where almost 50 % more energy is absorbed at 160° F. for an initial energy of 45 ft.-lb. than for the higher initial energies.

The curves of reduction in area vs. temperature have almost the same features as the curves of energy absorption. This is to be expected from the linear relation between impact energy and reduction in area shown in Fig. 10. Also, because of this relation, the curves of impact energy per unit of fracture area show almost the same features as the curves of impact energy per unit of original area at the root of the notch.

Transition temperatures determined from these various curves are reported in Table 11. The transition temperatures obtained from reduction in area are in every case within 5° F. of those determined from impact energies. The transitions determined from the fracture area-impact energy curves vary from 5° lower to 20° higher, but are generally just slightly higher than the transitions determined from impact energy alone. The transitions determined from the point where a 15 % reduction in area is obtained are generally 5 to 10° lower and in some cases range up to 15° lower than the transitions determined from impact energy.

Conclusions

Effect of Initial Energy

The transition temperatures for project steels E, A, C and D are plotted in Fig. 20 as a function of the initial energy of the pendulum of the testing machine. It appears that steels E and C have approximately constant transitions of 115 and 110° F., respectively. However, steels A, Dr and Dn show a significant decrease in transition temperature with decrease in initial energy.

From tests at 220 ft.-lb. only one could not conclude that steel A is less notch-sensitive than steel C. However, at 45 ft.-lb. the transition temperature of steel A is clearly 30 to 45° F. lower than that of steel C. This is consistent with results of the static tests of wide plates, but the separation of the two steels is not quite as great in the axial impact tests as in the wide plate tests.

This result suggests the possibility of obtaining more reliable information from the ordinary Charpy tests, which does not separate steels A and C as shown in Table 12. Perhaps a more distinctive result would be obtained with the Charpy test at a lower initial energy level.

In these tests the different values of initial energy

Table 9—Series 7. Tension Impact Tests of Type B Specimens of Killed, As-Rolled Steel Dr. Tests Made with Initial Energies of 220, 110 and 45 Ft.-Lb.

Initial Energy, ft. lb.	Specimen Number	Testing Temp., deg. F.	Impact Energy, ft. lb.	Impact Energy, ft. lb./in.^{2}	Per cent Shear	Per cent Reduction of Area
220	H19	140	31.1	458	85	36.9
	H20	140	29.0	427	--	35.1
	H 8	100	28.8	428	20	34.0
	H 9	100	28.7	420	20	34.8
	H 1	77	29.9	438	40	34.8
	H 2	77	29.2	428	40	36.0
	H11	70	24.1	353	5	28.2
	H12	70	28.8	424	10	31.7
	H25	70	34.4	510	55	32.4
	H 5	60	20.0	293	1	21.6
	H 6	60	19.9	294	2	21.2
	H 7	60	28.4	416	2	31.0
	H21	60	27.6	405	5	31.3
	H22	60	27.2	398	55	32.1
	H13	50	24.9	365	2	27.6
	H14	50	10.9	161	1	8.7
	H23	50	25.6	375	--	27.5
	H24	50	21.9	352	--	24.8
	H 3	40	16.4	242	--	16.8
	H 4	40	14.4	211	--	14.6
	H15	20	13.4	197	--	10.6
	H16	20	16.8	247	--	11.9
	H17	-20	11.5	169	--	6.32
	H18	-20	12.9	190	--	7.36
110	H26	82	27.0	398	10	33.5
	H28	82	29.8	436	15	34.8
	H29	70	27.8	410	5	30.6
	H30	70	30.8	454	10	35.0
	H31	60	30.5	455	10	33.6
	H32	60	29.7	437	10	33.9
	H33	50	29.0	427	10	30.0
	H34	50	26.9	440	5	35.0
	H35	40	28.5	417	2	29.1
	H36	40	27.9	411	2	31.1
	H37	32	25.0	371	1	16.3
	H38	32	26.5	390	2	30.0
	H47	20	22.0	322	1	18.0
	H48	20	16.1	249	1	14.5
	H41	10	17.8	260	0	15.5
	H39	10	9.9	145	0	9.2
	H49	10	15.8	231	0	14.9
	H40	0	8.5	125	0	7.96
	H42	0	9.8	144	0	8.5
	H50	0	10.8	159	0	8.4
	H43	-20	10.2	150	0	7.9
	H44	-20	13.5	198	0	7.8
	H45	-60	8.8	130	0	5.2
	H46	-60	12.0	175	0	5.3
45	H 4	120	34.6	505	93	38.8
	H 3	120	34.2	501	98	36.1
	H 2	87	35.9	522	97	36.4
	H 1	87	34.8	506	95	34.8
	H 5	60	35.6	520	15	34.3
	H 6	60	34.4	500	15	34.3
	H19	50	34.8	505	15	35.3
	H18	50	33.6	489	80	33.1
	H20	32	35.1	510	15	34.2
	H 7	32	34.8	505	10	32.2
	H 8	32	30.9	446	5	28.4
	H 9	20	33.6	488	5	31.7
	H25	20	25.0	363	2	22.2
	H21	20	19.2	279	1	16.1
	H11	20	17.2	250	1	14.2
	H22	10	19.1	279	1	14.9
	H12	10	18.2	266	--	14.3
	H24	10	16.2	238	--	10.5
	H13	10	14.2	207	--	9.9
	H14	0	18.1	263	--	13.0
	H15	0	17.8	259	--	12.3
	H17	-20	15.5	225	--	8.6
	H16	-20	14.8	215	--	8.0
	H23	-40	14.2	208	--	6.6
	H10	-40	13.2	156	--	6.1

Table 10—Series 7. Tension Impact Tests of Type B Specimens of Killed, Normalized Steel Dn. Tests Made with Initial Energies of 220, 110 and 45 Ft.-Lb.

Initial Energy, ft. lb.	Specimen Number	Testing Temp., deg. F.	Impact Energy, ft. lb.	Impact Energy, ft. lb./in.^{2}	Per cent Shear	Per cent Reduction of Area
220	G19	140	31.5	462	95	43.9
	G20	140	30.8	457	97	44.4
	G 8	100	31.2	460	70	42.0
	G 9	100	30.9	452	75	42.1
	G 1	77	29.2	430	35	37.7
	G 2	77	30.6	448	--	38.6
	G11	70	26.2	383	10	33.4
	G12	70	29.2	427	10	36.5
	G25	70	28.4	417	5	33.6
	G 5	60	19.2	281	2	24.0
	G 6	60	12.2	179	1	15.2
	G 7	60	20.0	292	2	23.9
	G21	60	22.8	333	5	27.8
	G22	60	20.7	301	--	26.9
	G13	50	20.8	306	--	25.3
	G14	50	23.0	338	--	25.9
	G23	50	16.4	240	--	16.6
	G24	50	20.1	294	--	23.4
	G 3	40	13.6	198	--	13.1
	G 4	40	13.0	190	--	16.0
	G16	20	11.9	174	--	9.23
	G15	20	13.1	193	--	10.0
	G17	-20	11.0	162	--	6.31
	G18	-20	11.8	173	--	6.31
110	G44	160	34.0	501	100	42.5
	G42	160	32.5	479	100	43.3
	G37	120	35.5	523	99	45.2
	G39	120	33.5	492	100	43.3
	G64	84	33.5	497	80	41.3
	G52	84	33.0	485	95	42.4
	G46	84	29.5	435	80	42.0
	G66	60	33.5	490	20	41.3
	G40	60	29.5	435	20	36.1
	G31	40	30.	442	10	35.1
	G68	40	21.5	323	2	32.9
	G45	30	22.0	322	2	22.2
	G47	30	16.4	234	1	16.1
	G32	20	19.5	288	1	21.2
	G27	20	12.5	186	1	12.3
	G33	0	9.5	140	--	7.4
	G34	0	8.5	126	--	7.4
	G50	-40	8.5	125	--	6.5
	G48	-40	8.5	125	--	6.8
45	G73	120	36.6	536	100	42.4
	G71	120	36.0	527	100	43.8
	G65	84	37.2	545	98	43.8
	G70	84	35.6	520	98	40.2
	G75	60	34.5	512	50	38.8
	G74	60	34.4	508	60	39.7
	G62	40	36.9	548	90	40.3
	G35	40	33.5	490	70	38.2
	G57	32	34.9	515	10	39.7
	G58	32	34.8	508	5	39.1
	G61	20	36.8	538	5	40.3
	G41	20	34.2	501	5	36.5
	G69	20	30.6	448	5	32.9
	G29	20	30.2	445	2	31.6
	G43	20	12.7	185	--	10.4
	G60	10	30.3	445	5	31.0
	G59	10	18.5	271	1	17.4
	G36	10	17.8	262	1	16.3
	G56	10	8.0	117	--	18.6
	G26	0	15.1	221	--	12.4
	G28	0	13.5	198	--	9.2
	G30	-20	13.8	203	--	9.3
	G62	-20	12.9	189	--	7.9
	G54	-40	11.2	164	--	5.3
	G53	-40	10.5	156	--	4.8

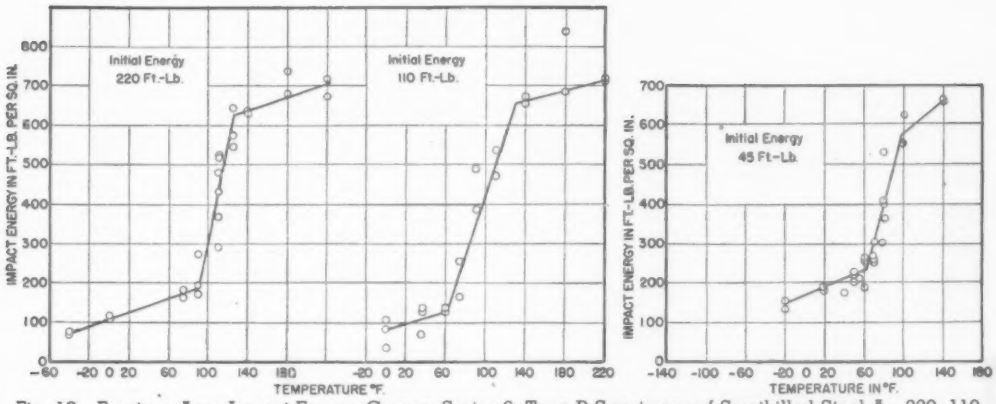


Fig. 18—Fracture Area-Impact Energy Curves, Series 6, Type B Specimens of Semikilled Steel A; 220, 110 and 45 Ft.-Lb. Initial Energy

Table 11—Summary of Transition Temperatures

					Estimated Transition Temperature, ° F., from		
Series	Steel	Specimen Type	Initial Energy, Ft.-Lb.	Impact Energy	Reduction of Area	Reduction Area, 15%	Impact Energy-Fracture Area
1	E	A	220	115	...	...	...
3	E	B	220	125	...	110	..
		C	...	90	...	75	...
		D	...	100	100	90	...
4	E	E	220	130	130	130	140
		F	...	140	140	130	150
		G	...	150	150	145	160
		H	...	130	130	120	135
5	E	B (standard)	220	120	125	105	140
			110	115	115	105	120
			45	120	125	105	115
			33.8	110	115	110	110
6	A	B (standard)	220	105	110	95	110
			110	85	85	80	90
			45	80	75	70	80
6	C	B (standard)	220	110	115	110	115
			110	110	115	110	110
			45	110	110	100	110
7	Dr	B (standard)	220	55	55	45	55
			110	20	25	15	25
			45	20	20	15	20
7	Dn	B (standard)	220	60	55	45	60
			110	30	30	20	35
			45	15	15	10	15

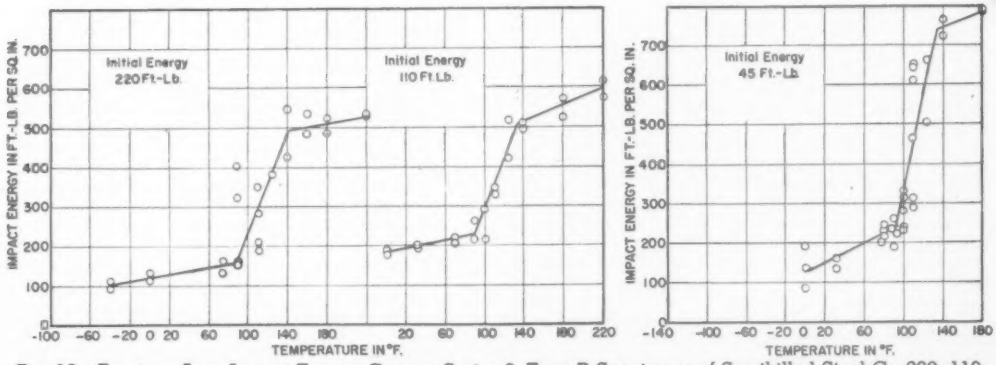


Fig. 19—Fracture Area-Impact Energy Curves, Series 6, Type B Specimens of Semikilled Steel C; 220, 110 and 45 Ft.-Lb. Initial Energy

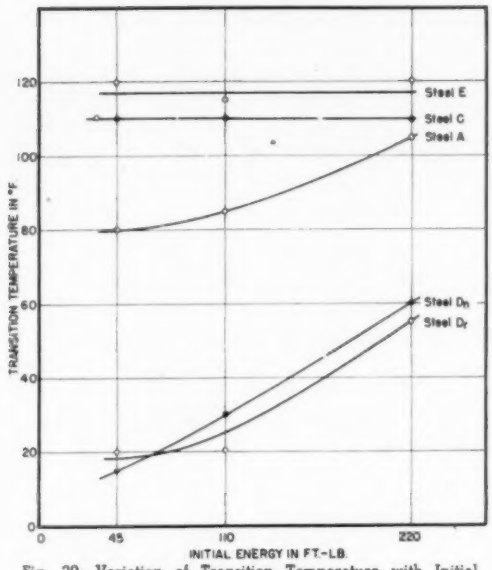


Fig. 20—Variation of Transition Temperature with Initial Energy for Several Steels

were obtained by changing the height but not the mass of the pendulum. That is, the velocity of the pendulum was altered. Further studies are planned in which the initial energies are varied while the velocities are kept constant. However, it must be noted that the variations in velocity required to achieve the different initial energies in this report are relatively small. And there is certainly a difference in the behavior of the different steels with changes in initial energy.

Comparison with Wide Plate Tests

At the initial energy level of 45 ft.-lb., the transition temperatures determined by axial impact tests differed from those determined by tests of 72-in. internally notched wide plates by the following amounts: for steel E, 20° higher; for steel C, 20° higher; for steel A, 45° higher; for steel Dr, 10° lower; and for steel Dn, 13° lower. On the whole, this constitutes a fair agreement, not only in relative order, but also in actual temperature of transition between ductile and brittle fracture.

Table 12—Transition Temperatures of Charpy Notch Impact and of Wide Plate Specimens of Project Steels

Type of Test	Transition Temperature, °F., for Project Steel E	A	C	Dr	Dn
Charpy					
V-notch	150	90	100	45	30
Keyhole-notch	30	0	15	−60	−60
Wide Plates, In.					
72	100	35	90	30	28
24	100	−7 to +37	88	35	35
12	90	25	90	40	5

General Features of Axial Impact Tests

The most consistent results are obtained from axial tension impact tests when the specimen is notched in such a way that practically all of the energy must be absorbed in the region of the notch. The Type B specimens filled this condition. Sharper and more definite transition regions are obtained at the lower values of initial energy. An extremely sharp notch is not required to give transition temperatures in the range of those determined from static tests of large plates with internal notches.

One of the most interesting features of the test is the possibility of using reduction of area at the root section to determine the transition range. This means that simpler testing machines can be used; drop-testing machines, for example, would be adequate, and only measurements of temperature and diameter before and after fracture are required. Another possibility is to use an initial energy capable of fracturing a specimen in the brittle range but not in the ductile range. This would make even the measurement of diameter change unnecessary.

References

1. Wilson, W. M., Hechtman, R. A., and Bruckner, W. H., "Cleavage Fracture of Ship Plate as Influenced by Size Effect," U. S. Navy, NObs-31224, Serial No. SSC-3, Progress Report, Aug. 20, 1946.
2. Wilson, W. M., Hechtman, R. A., and Bruckner, W. H., "Cleavage Fracture of Ship Plate as Influenced by Size Effect," U. S. Navy, NObs-31224, Serial No. SSC-10, Final Report, June 1947.
3. Davis, H. E., Troxell, G. E., Parker, E. R., Boodberg, A., and O'Brien, M. P., "Cleavage Fracture of Ship Plate as Influenced by Design and Metallurgical Factors (NS-330): Part II-Flat Plate Tests," OSRD 6452, Serial No. M-608, January 1946.
4. Klier, E. P., Wagner, F. C., and Gensamer, M., "The Correlation of Laboratory Tests with Full Scale Ship Plate Fracture Tests," The Welding Journal, 27 (2) Research Suppl., 71-s to 96-s (1948).

Discussion by Wendell P. Roop*

The paper proposes the energy value found in a notched tensile bar tested in an ordinary impact machine as a criterion for selection of a steel for structural use. Since the strength of structural steels is already adequately measured by the unnotched tensile bar under static load, it is understood that the quantity to be evaluated in the proposed manner is the ductility of the material in the notched condition.

The use of energy absorption in a laboratory test as an index of working ductility is widely accepted and needs no comment. The question is whether the proposed test treats the material in a manner enough like the static tensile test of a notched plate to assure correlation of results by the two tests.

The Charpy test is agreed to be inadequate for this purpose because of its famous failure to discriminate between "A" and "C" steels. Slow bend tests of specimens similar to the Charpy are better in this respect. The impact tensile test is stated to effect the desired discrimination provided a sufficiently slow-moving pendulum is used. All this suggests that the cause of the failure of the Charpy test lay in the impact loading, and that a static test is preferable.

As between bending and tensile loading, I agree with the authors in preferring tension. The notch is necessary as everyone agrees. If then the static test is preferred and impact loading is confined to low hammer speeds and

* Swarthmore College, Swarthmore, Pa.

used then only for its convenience in quick energy determination, the only remaining question would relate to the choice between a round bar and a flat bar, such as permits use of an internal notch.

The notched round bar has had extensive use by Sachs and his associates, and at the A.S.T.M. Symposium of June 1948 in Detroit he gave extensive data, part of which may be applied to the results of the work reported in the present paper. Sachs's work was done on medium steel of the general sort used in structures, but of higher strength. In the plastic stress-strain curve represented by $\sigma = ae^{1/4}$ the value of the constant "a" in Sachs's steel was 124 psi., as compared with 110 for the A and E steels. Of this material, Sachs tested a specimen, among others, which was close in geometry to the standard specimen of Bruckner and Newmark. By integrating his curve of stress on strain (from reduction in area at the root of the notch), I find the average unit energy value in the notch of Sachs's specimen to be 54,000 in.-lb. per cubic inch. The corresponding figure for the unnotched bar of the same sectional area is 77,500. In a steel in which the curve lay at 110/124 of the stress values, these figures would come to 48,000 and 69,000, and these are the values which will presently be used.

The main purpose of the work of Bruckner and Newmark was to justify use of the proposed specimen for finding the temperature of the ductile-brittle transition, and the method of doing this was by using the specimen for finding this transition value in a variety of cases for which a corresponding value was accepted for the 72-inch plates. Table 11 of the paper shows the extent to which this was accomplished. Even if the results of Table 11 had given better evidence of correlation of this wholly empirical sort, it still would not be certain that further application of this method might not yet bring forth a new surprise like the failure of the Charpy test on A and C steels. This uncertainty would diminish only gradually if, and as, good correlations were obtained between the new specimen and large flat plates of more and more different samples of steel; unless, that is, some *a priori* expectation of such correlations can be established.

What are the prospects of *a priori* justification of a specimen like this? Is it possible to analyze the action of the specimen so as to obtain from it a measure of the ductility of a sample of steel which we may be sure will agree with the value obtained from a notched flat plate specimen?

In exploring this possibility we note first that although a variety of results were obtained with the round bar as the parameters were varied (area of net section, depth of notch, acuity of notch, striking speed of hammer), yet for the most part these variations were not great enough nor the tests numerous enough to distinguish systematic differences from those due to scatter. Exceptions to this occur, as in the case of the high values found in the larger sections, as shown in Table 4. But if the fact of scatter be fully accepted, positive effects of varying the parameters in these tests are hard to identify. This comment applies in the first instance to the energy values in the fully ductile mode, but uncertainty in energy values is also reflected in some degree in the transition temperatures.

The most numerous tests were made on the E steel, and I have chosen it for detailed attention. The fully ductile energy seldom departs widely from 430 ft.-lb., or 5160 in.-lb. per square inch of net section. If a value of 69,000 in.-lb. per cubic inch be drawn from Sachs's data, the average axial length sharing in the plastic flow in the notched specimen may be estimated at 5160/69,000 or 0.075 in., roughly equal to the axial length of the notch. This comparison ignores the difference between static and impact loading, which may be less serious for this purpose than in finding the transition temperature.

If it be said that it also ignores the effect of geometry on ductility, I prefer to restate this by saying rather that the comparison rests on a very simple and perhaps crude hypothesis about the nature of that effect, as follows: that energy absorption in any form of specimen in the fully ductile temperature range may be estimated by applying to the volume of metal judged to share in the flow a value of the energy absorption per unit volume in an unnotched tensile bar.

Application of this hypothesis depends on correct gaging of the effects of localization and triaxiality. As for localization, it is a matter of familiarity with patterns of strain distribution. But around the word "triaxiality" hangs a curtain of mystery which should be drawn aside. The authors seem in the paper under review not to have used this word but the difficulty is a real one and not to be evaded.

As hypothesis, again, and certainly not yet as proved, perhaps only as approximately true and subject to exceptions, I make the following further assertion:

> . . . that at temperatures above the brittle transition, ductility (local unit energy absorbed before fracture) found by integrating the octahedral stress strain curve is not affected by triaxiality.

The use of octahedral values is all that is needed to account for the effects of triaxiality.

An apparent contradiction of this hypothesis is found in Sachs's paper, of which Fig. 10 shows ductility to fall off sharply as notch sharpness increases, and moderately with increase of notch diameter. In the present paper the limited data on this point show no effect of sharpness alone on ductility but high ductility values in specimen types C and D in which both sharpness and diameter were higher than in the standard. So far as they go, these results are contrary to those of Sachs, but they are not very conclusive, and we may accept the widely held idea that increasing notch sharpness reduces rather than increases ductility.

It does so, however, by affecting the localization and the triaxiality. To prove the hypothesis wrong we would have to show that as notch sharpness changed, the area of the octahedral stress-strain curve to the fracture point failed to keep pace with the observed energy absorption. According to the hypothesis, the fracture begins at the same point on the octahedral stress-strain curve regardless of how much the values of the average axial components of stress and of strain in the minimum section at fracture may be reduced by increasing notch sharpness.

Returning to the data of Bruckner and Newmark, we will suppose, first, that the effects of impact are small, so that inferences from static tests are applicable. Fracture begins on the axis, and the cavity thus opened expands outward until, as it reaches the surface of the metal, the parting is complete. At the start of the fracture, slip has occurred mainly on the surface of a double cone whose vertex is at the point of intersection of the axis with the plane of the minimum section. The included angle of this cone is taken to be 2 x 45° although it actually is a little smaller. The proportions of the specimen are such that the cone does not intersect the bounding surface of the metal except beyond the limits of the notch, where the intensity of octahedral stress and strain has faded to a value so low that the energy absorption there may be neglected.

Within the notch, between its parallel transverse boundary planes, we will suppose that the metal is strained to near its breaking point over the whole surface of the cone. As the cavity expands outward, the strain in the metal within the cone, near the axis, ceases to grow,

but between the two branches of the cone the advancing crack carries with it a conical slip surface on which the strain continues to approach the breaking point. This surface sweeps through the entire volume of metal lying outward and between the branches of the central cone, and the metal there is worked right up toward its limit.

On the basis of this picture of what happens, the total energy value given by the impact machine could be divided by the volume of metal in the restricted region of the notch to get a nominal value of the unit energy absorption comparable with that found in the tensile test of an unnotched bar.

When the energy values of Bruckner and Newmark are reduced in this way they give a close check. Taking, for example, the representative number of 5160 in.-lb. per square inch and dividing by the length of the notch, 0.078 in. in the Type B specimen, gives 66,000 in.-lb. per cubic inch, as compared with 69,000 average in the minimum section of the unnotched bar.

It is noted that in the data themselves evidence is found to support the criticism that the impact values include items of energy wholly extraneous to the flow of the metal near the fracture, such as that lost by elastic waves set up by the blow, as well as items nearer home like deformation in the screw threads on the specimen. Figures 6 to 10 suggest that such losses may amount to as much as 100 ft.-lb. Deduction of such a correction would bring the observed energy value into nominal agreement with the value of 48,000 in.-lb. per inch drawn from the static tests of Sachs for specimens of the same geometry.

All of the energy values so far cited have been found by direct observation, either by measurement of the loss of energy in the pendulum of the impact machine, or by integration of a curve of stress on strain. For comparison with these we will now take out some local values found by applying octahedral theory to the axial strain based on reduction in area. The unit energy is

$$u = 0.96\, a\, (1 - m + m^2)^{5/6}\, \epsilon_1^{5/4}$$

where a is the coefficient in the stress-strain curve $\sigma = a\, \epsilon_1^{1/4}$ and $m = -\epsilon_3/\epsilon_1$ is the ratio of the intermediate to the maximum strain value. Since

$$\epsilon_1 + \epsilon_2 + \epsilon_3 = 0, \quad \frac{-\epsilon_3}{\epsilon_1} = 1 - m.$$

Taking $a = 110$ and $m = 1/2$ the energy value is

$$u = 88\, \epsilon_1^{5/4} \text{ inch-kips/cu. in.}$$

This formula has been applied to the data in Fig. 10 by converting reduction in area to axial strain and assuming that the same value holds throughout the volume of metal in way of the notch. The energy thus calculated falls well below the observed values. It is inferred that the energy is mostly absorbed in way of the notch, but that irregular additional amounts of energy leak out elsewhere.

The tests, of course, were designed, not to measure specific ductility, but only to find the temperature limit below which a large reduction in ductility occurs. It is possible that even a large dilution of the energy absorbed in the notch might still leave a differential large enough to indicate this temperature effect. However data subject to this difficulty would not be suitable for indicating the form of the transition curve and would not help settle the controversy as to where on the curve the threshold of brittleness should be considered to lie. They would lack the *a priori* support needed for complete justification of the method. The presence of such extraneous energy would explain the low correlation in these tests between energy values and appearance of fracture.

Finally, some comment will be made on steels A and C. Their energy values in the fully ductile condition are about the same as in the other steels, and do not vary much with pendulum speed. Those for C steel are a little less than for A steel whereas in the plate tests it was the other way round. However, neither difference is critical.

The transition appears clearly in Figs. 14 and 15, and is about the same whether judged by impact energy or reduction in area. When the data in Tables 7 and 8 on per cent shear fracture are plotted, the transition seems to be higher in all cases, with discrimination between the steels even at the higher striking speed. By the criterion of appearance of fracture a shift toward lower transition seems to go with lower-striking speeds in both steels, whereas by the other criteria the shift occurs in A but not in C steel; discrimination then depends on the presence of the shift in A and its absence in C. The amount of the difference between the steels is small at most, said in Table 11 to vary from 5 to 30°. But the curves as drawn show large variations in form and it cannot be said that the precision with which these transitions have been located justifies more than qualitative conclusions.

The transition temperatures cited in Table 11 will naturally be compared with those found by other methods of test; without now going into such a comparison, we may be sure that it will not resolve the existing confusion and uncertainty until the analysis of all the data has been carried much further. It is my own feeling that these troubles will not be cured until we can place the measurement of specific ductility on a rational basis.

The fact that the prediction of energy absorption in the notch on the basis of data from an unnotched specimen succeeds at all suggests that all that is needed is a method of correcting for extraneous energy. If by such an expedient the notched round tensile bar, even under impact load, might be assigned a conversion factor by which its ductility values could be reduced to terms of the notched tensile plate, a great step forward would be taken. Cold as a cause of brittleness would then be divorced from its troublesome companion triaxiality, to the benefit of clear thought about both of them.

It is fairly clear how triaxiality can reduce ductility above the transition temperature, and the hypothesis I have proposed puts the burden of explaining this on octahedral theory. But this hypothesis says nothing as to why triaxiality raises the transition temperature.

It has been suggested that fracture strain may change with triaxiality. The whole concept of "hypothetical fracture stress" was discussed at length by Lubahn a year ago at the Chicago seminar, as in the A.S.M. volume on *Fracturing of Metals*. That discussion leaves me with the feeling that a sample of metal at a temperature below the threshold of brittleness is simply a different sample from one of the same metal above the threshold.

It comes to this, that we have a better chance to describe the behavior of a sample of metal consistently if we can get past the purely relative comparisons and deal in terms of ductility as a measurable property.

Discussion by George Irwin* and J. A. Kies†

The Riehle machine of Fig. 1 appears to have the specimen protruding from the pendulum head at right angles to the pendulum arm and in a line intersecting the center of the striking edge used in Charpy impacts. This geometry can produce an appreciable deviation from axiality

* Mechanics Division, Naval Research Laboratory, Washington 20, D. C.
† Ballistics Section, Mechanics Division, Naval Research Laboratory.

of the load applied to the specimen. At the instant of impact the leading and trailing ends are moving downward at different rates as well as forward. The vertical plane contact of the anvil and cross bar tend to keep the trailing end of the specimen horizontal while the leading end is moving down as well as forward. Bending occurs at both ends of the test section but in opposite sense. An unnotched ductile specimen exhibits this double bending quite markedly under such conditions. Bending is less in an arrangement such as that of Clark and Duwez (*Jnl. App. Mech.*, Sept. 1948, p. 243) in which the specimen axis is tangent to the circle of motion at the leading end of the specimen. It is difficult to obtain high accuracy of axiality in a tensile impact test of a ductile metal in a pendulum type machine, but for practical interpretations of the results such deviations may be unimportant. The authors' final conclusion is to be strongly commended.

The reduction of area shown in Fig. 10 gives the same qualitative picture as when the percentage brittle or granular fracture is plotted against impact energy. Every curve showing energy vs. reduction of area or percentage granular fracture should intercept the energy axis at some positive value greater than the surface energy of the fracture i. e. the energy for completely brittle fracture. It is of considerable interest to know how small this intercept really is in fast and brittle type fractures. It would be interesting to see whether the curves shown in Fig. 10 are statistically more significant than similar curves showing percentage granular fracture. In any case a sound procedure would be to do enough tests to obtain two results for comparison which had equal statistical significance.

By applying the "t" test as described in Rider's "Modern Statistical Methods" it can be shown that there is only a 1% chance that the energy intercept for specimen Type F would deviate by 22.4 ft.-lb. or more in a repeat experiment and there is a 10% chance of a deviation of 13.8 ft.-lb. Such reliability is very good for an experiment of this kind.

On examining the data for specimens of Type H, one can show that there is a 1% chance of a y intercept deviation of 44.5 ft.-lb. or more in a repeat experiment and a 10% chance of a deviation of 27.5 ft.-lb. or more. Thus the dependability of the y intercept for a regression curve (least squares) for Specimen H is relatively poor and many more tests for Specimen H than for Specimen F are required in order to place equal confidence in the location of the curve. The chance that the y intercept for types F and H are the same is negligible.

It seems likely that if significance tests were applied to impact energy vs. percentage granularity and impact energy vs. reduction of area that the latter might be found to be a more reproducible relation.

For the purpose of evaluating the serviceability of steels for shock loading and notched conditions it would be just as desirable to know the scatter in performance as the average values. If the Charpy test shows more scatter than the tensile impact test, then the Charpy test has an advantage provided that the scatter is not due to uncontrolled variables in the test itself. In view of the difficulty often encountered in establishing a good numerical correlation between serviceability, or service failures, and Charpy impact results (those of Williams and Ellinger excepted) the burden of proof is still on the Charpy test, and we feel justified in searching for a simpler and more reproducible test such as the type sought by Bruckner and Newmark. In view of the nature of all such tests it seems desirable to include statistical analyses of the data, especially in comparing the utility of two types of test such as Charpy and tensile impact.

With reference to the general applicability of the authors' tensile impact technique for judging the transition temperatures of large centrally notched plates under slow speed tensile loading, we would like to know to what extent the effect of strain aging in the large plates during the test must be considered. The data of Gensamer and others (Progress Report on "Correlation of Laboratory Tests with Full Scale Ship Plate Fracture Tests," NRC, Mar. 19 1947) showed that an approximate correlation of Charpy impact test transition temperatures with the same large plate results referred to by the authors was obtained when the materials were strained 10% and aged prior to making the Charpy specimens.

Discussion by E. P. Klier*

Recent work which we have completed† has indicated that for the project steels in certain tests satisfactory correlation does not exist for transition temperatures determined from energy absorption and from fracture appearance. Differences between data for fracture appearance and several other criteria of transitional behavior have been discussed by Stout and McGeady.‡ The data which the authors have presented among their other interesting features are pertinent to a discussion of transitional behavior.

The data for fracture appearance from Tables 6, 7, 8 and 10 were plotted and transition temperatures were determined at 50% fibrous fracture. These transition temperatures are plotted in Fig. 1 for comparison with the author's Fig. 20.

It is evident, first of all, that the steels are no longer evaluated in the same order as for energy absorption. By fracture appearance the steels in order of decreasing transition temperatures are C, E, A and D_n. The curves for steels A and C are separated by about 40° F. with Steel A having the lower transition temperature.

The author's initial energy effect—this is probably a velocity effect—is observed for all steels, and in this connection a seemingly important effect is observed. The transition temperatures for fracture appearance lie from 20 to 40° F. above the respective transition temperatures by energy absorption for an impacting hammer energy of 220 ft.-lb. As the impacting hammer energy is decreased the transition temperature by fracture appearance drops at seemingly a greater rate than it does by energy absorption. Because of this the transition temperatures for steels A and E by fracture appearance and energy absorp-

* Pennsylvania State College, State College, Pa.

† Klier, E. P., Wagner, F. C., and Gensamer, M., "Fracture Characteristics of Ship Plate in Certain Small-Scale Tests," Preprint Annual Meeting Papers, 45-61, also in this issue, p. 50-s.

‡ Stout, R. D., and McGeady, L. J., "The Meaning and Measurement of Transition Temperature," THE WELDING JOURNAL, RESEARCH SUPPLEMENT, XIII (6), 299-s to 302-s (1948).

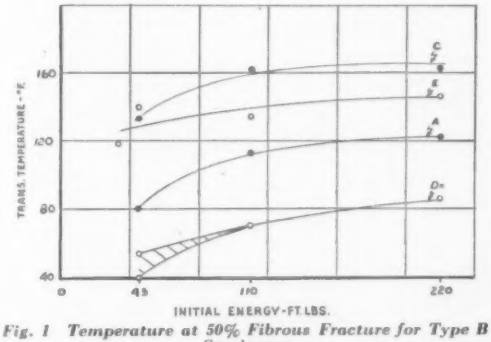


Fig. 1 Temperature at 50% Fibrous Fracture for Type B Specimens

tion are equal for impacting hammer energies of 45 and 33.8 ft.-lb., respectively. Similar results are indicated for the remaining steels.

It is interesting that the transition temperature by energy absorption for Steel A increases and becomes equal to those for steels C and E at high impacting energies.

Discussion by I. R. Kramer

Upon examination of the data presented in Fig. 20, it is believed that the effect shown is due to the change in velocity of impact rather than that due to the change in the initial impact energy. Since only the height of the pendulum was changed, it might be of interest to redetermine the curves of Fig. 20 by changing the velocity of impact and mass of the pendulum in a manner such that the kinetic energy remains constant.

If the effect is that of strain rate, then a metallurgical interpretation of the behavior of the steels may be possible. It is known that the impact transition temperature increases as the impact velocity increases. This effect would predict curves with a positive slope similar to those of steels A, Dn and Dr of Fig. 20. However, it is possible that plastic strains produced during the testing can cause precipitation to occur. The amount of precipitant will depend upon the time the plastic strains are allowed to act and the magnitude of plastic strains. For specimens subjected to slow strain rates both of these factors are large and more precipitation is likely to occur than in specimens strained at high rates. Since the brittleness will increase with the amount of precipitant, the transition temperature will also be raised. It would be possible for curves similar to those of Fig. 20 to have a negative slope if the effect of precipitation is sufficiently great.

It is of interest to note that curves of the more brittle steels have the lowest slope. For example, steels E and C have a zero slope while that of steel A is lower than that of steel Dn and Dr. Since precipitation is a factor which may influence the behavior of these steels, it may be that the slope of curves is significant as an index of brittleness.

I. R. Kramer is connected with the Office of Naval Research, Washington, D. C.

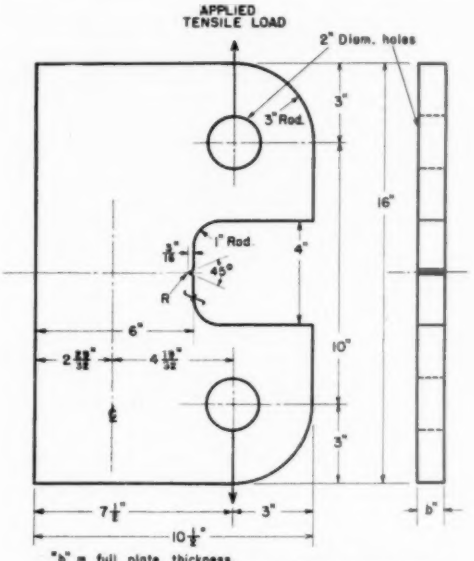
Discussion by A. B. Bagsar*

This interesting paper has brought out several important items which deserve further consideration.

The first item to be recognized is the fact that the energy of fracturing of a given metal evaluated by small test coupons, such as those used in impact tension and standard impact tests, is mainly determined by the behavior of the metal at the surface, where the stresses are essentially biaxial. Due to the smallness of the cross-sectional area involved and the nonrigidity inherent in these test coupons, the energy of fracturing of the surface constitutes the predominating percentage of the total energy required to fracture the entire section. Therefore, these measurements do not necessarily represent the true behavior of the metal immediately below the notch or in rigid sections, where the stresses could be of triaxial type. It is essential to know the behavior of a metal under multiaxial stress conditions in order to evaluate its behavior under service conditions, even if this evaluation is only approximate.

Test data seem to indicate that a rectangular beam or section of dimensions considerably larger than those of impact coupons, preferably containing a sharp notch, say with a radius of the order of 0.0015 in., yields results which appear to be more nearly representative of the behavior of steel under service conditions.[1] The breaking and yielding loads of the large test coupons of the latter type conform to the conventional concepts of mechanics of materials, and these loads could be directly utilized by the designer as indexes of quality of the steel. Figure 1 shows the details of such a test coupon, which has been used by the writer and designated D-type "cleavage-tear" test coupon. The rate of loading to fracture is about 2 in. per minute of cross-head separation of the tensile-testing machine. Transition temperatures and other characteristics of steels are determined by simply measuring the breaking and yield loads. In Fig. 2 are shown transition curves of several steels, established by the use of this test coupon. These steels cover the thickness range of $^1/_2$ to $2^1/_4$ in., the chemical and physical properties of which are given in Table 1. For comparison, the transition curves of the same steels determined by the standard Charpy impact test using the keyhole coupon are also included in this figure. It is to be observed that these steels are classified in the same general order by the two testing methods, with respect to their transition characteristics. Figures 3 and 4 show fractured test coupons of 1- and $2^1/_4$-in. thick steel plates, respectively, below and above the transition temperatures. The top views in Figs. 3 and 4 are typical of the cleavage or brittle, and the bottom views typical of the shear or ductile fractures.

The second item to be noted is that the authors have



"b" = full plate thickness.
"R" = notch root radius = 0.0015", or as specified.

Fig. 1—Cleavage-Tear Test Coupon, D-Type. Tensile Load Is Applied Through Pins Inserted in the Loading Holes. Due to Eccentric Loading, the Section Is Broken by a Combination of Axial Tension and Bending Stresses

* Chief Metallurgical Engineer, Sun Oil Co., Philadelphia, Pa.

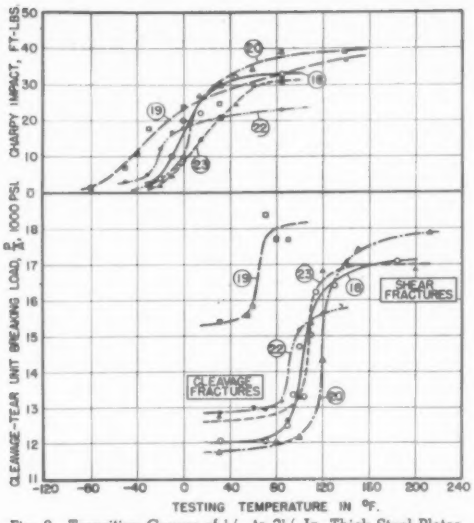


Fig. 2—Transition Curves of $^1/_2$- to $2^1/_4$-In. Thick Steel Plates, Determined by the Standard Charpy and Cleavage-Tear Tests

not used the "fracture appearance" as a basis for establishing transition characteristics. Not using fracture appearance as the determinant of transition characteristics is a desirable departure from the practice advocated by several investigators, with which departure the writer agrees. It is the writer's experience that even with the use of large test coupons of the type described, the temperature necessary to effect a marked change in fracture appearance may, in some combinations of section thickness or notch geometry, be considerably higher than the transition temperature indicated by breaking or yield

Table 1—Chemical and Physical Properties of Steels Tested

	Steel 18	Steel 19	Steel 20	Steel 22	Steel 23
Plate thickness, in.	1	1	$2^1/_4$	$^1/_2$	$^{15}/_{16}$
Chemical composition, %					
Carbon	0.20	0.17	0.18	0.20	0.25
Manganese	0.63	0.44	0.44	0.45	0.45
Phosphorus	0.020	0.014	0.014	0.020	0.015
Sulphur	0.033	0.023	0.026	0.045	0.024
Silicon	0.07	0.17	0.20	0.01	0.05
Tensile properties (fractures transverse to rolling)					
Tensile strength, psi.	61,300	65,700	62,000	60,500	63,500
Yield point, psi.	31,400	36,500	39,000	37,000	33,500
Elongation in 8 in., %	34.4	32.3	33.0	27.0	31.7
Grain size, normality and inclusion contents					
Actual grain size	5–7	7–8	5–6	8–9	5–6
Austenitic grain size	3–4	6	5–6	5–6	6–7
McQuaid-Ehn normality	Normal A heavy	Normal A heavy	Normal D heavy	Normal D thin 4	Normal C thin 2
Inclusion content and type	1 and D thin 3	1 and D heavy 2	5 and C thin 4	and A heavy 2	and D heavy 2

loads. An example of this was found in a $2^1/_4$-in. thick silicon-killed steel plate, designated Steel 20, whose transition temperature indicated by the P/A vs. T curve shown in Fig. 2 is 120° F. Yet in order to obtain in this steel the typically ductile or shear type of fracture shown in the bottom view of Fig. 4, it was necessary to raise the temperature to about 200° F. Similar discrepancies were also found in $^1/_2$- and 1-in. thick plates with the use of notches of root radii larger than about 0.0075 in. The appearance of fractures is therefore misleading unless its evaluation is made more precise than is obtainable by visual or macro examinations.

Fig. 3—Top View Shows Cleavage and Bottom View Shear Fractures Obtained in Steel 18, 1 In. Thick, Below and Above the Transition Temperature Range, Respectively

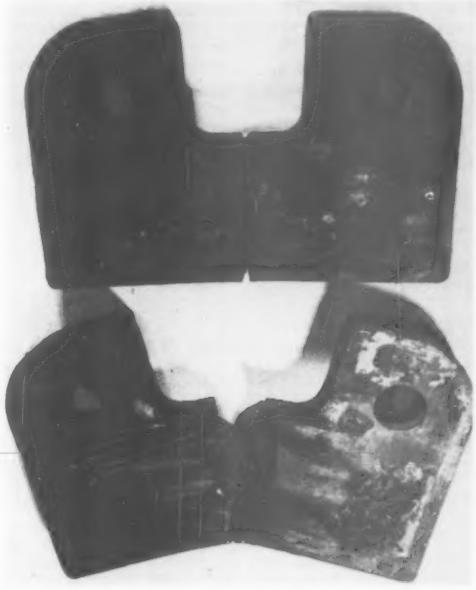


Fig. 4—Top View Shows Cleavage and Bottom View Shear Fractures Obtained in Steel 20, $2^1/_4$ In. Thick, Below and Above the Transition Range, Respectively

The third item is related to Fig. 20 of the paper. It is apparent from the curves presented in this figure that the transition temperatures of steels E and C are independent of the initial energy or striking velocity, and that presumably the latter temperatures of these steels could be determined equally as well by static tests, with the use of the same notch geometry. The curves for steels A, D_a and D_r, also given in this figure, show that with the use of the same notch root radius and notch angularity the transition temperatures of these steels are increased as the striking energy or velocity of impact is increased. This observation simply indicates that the latter steels are more "ductile" than steels E and C. Experimental data[1, 2] indicate that as the notch root radius is decreased a limiting dimension is reached beyond which the velocity of load application has no effect on transition temperatures. Accordingly, had the notch radius used been somewhat smaller, the transition temperature vs. initial energy curves obtained for the latter three steels would likewise be parallel to the horizontal axis, as in the case for steels E and C.

The fourth item that needs emphasis is the fact that determination of transition temperatures alone is insufficient to evaluate the quality or suitability of a metal for a given service. In the first place, the transition temperature of a given steel is not a fixed temperature, but can be increased by decreasing the notch root radius, or decreased by increasing the notch root radius, with other conditions being the same.[1] This is illustrated by Fig. 5, in which the logarithms of the transition temperatures (° F. absolute) of steels 18, 22 and 23 are plotted against the logarithms of the root radius of the notch. The limiting dimension for the notch root radius is obviously the dimension of the root radius of a cleavage crack.[3] The data for construction of Fig. 5 were obtained by the use of the test coupon shown in Fig. 1, which data are summarized in Table 2.

Another limitation of the direct use of transition temperature as an index of quality or performance consists in the fact that a steel which shows a lower transition temperature by a certain test may not necessarily be more suitable for a given service than another steel which shows a somewhat higher transition temperature determined by the same testing method. As the restraint to lateral flow is increased, say by decreasing the notch root radius and/or by decreasing the temperature,

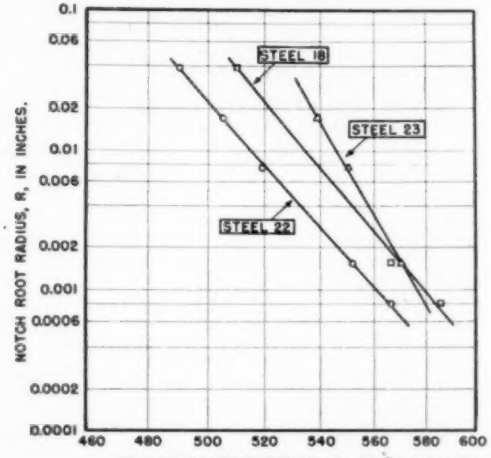


Fig. 5—Transition Temperatures of Steels 18, 22 and 23 as a Function of Notch Root Radius

Table 2—Transition Temperatures of Steels 18, 22 and 23 for Various Notch Root Radii

Notch root radius r, in.	Steel 18 Transition Temp., ° F.	Steel 18 T_a,* ° F.	Steel 22 Transition Temp., ° F.	Steel 22 T_a, ° F.	Steel 23 Transition Temp., ° F.	Steel 23 T_a, ° F.
3×10^{-6}	200†	195†	190†	205†	170†	150†
0.0008	125	120	105	120	...	...
0.0015	105	100	92	107	110	90
0.0075	...	...	58	73	90	70
0.017	...	...	45	60	80	60
0.039	45	40	35	50	...	...
Charpy transition temperature, ° F.	- 5	...	−15	...	20	...

* T_a = difference in transition temperatures determined by the Charpy and cleavage-tear tests.

† Extrapolated transition temperatures corresponding to cleavage crack as the notch.

a limiting temperature T_a, is ultimately reached, at which temperature the fracturing and yielding loads coincide with each other. It is well established that the yield point of steel increases with decrease of temperature, the degree of this increase being greatly accentuated in the presence of a sharp notch. This is substantiated by the curves shown in Fig. 6, in which the unit breaking and unit yielding loads of the three steels referred to above are plotted as a function of temperature.[1] The test data from which Fig. 6 was constructed are given in Table 3, these test data being likewise obtained by the use of the coupon shown in Fig. 1. It is to be noted that at or below the T_a temperature no appreciable yielding occurs in these steels during fracturing; they behave almost like ordinary gray cast iron. However, it is also to be noted that between the transition temperature, T_0, and the temperature T_a some yielding or ductility is possible which, although small in magnitude, may in some cases reduce stress peaks sufficiently to prevent failure by cleavage. The evaluation of these characteristics together with the determination of the transition and T_a temperatures are therefore necessary

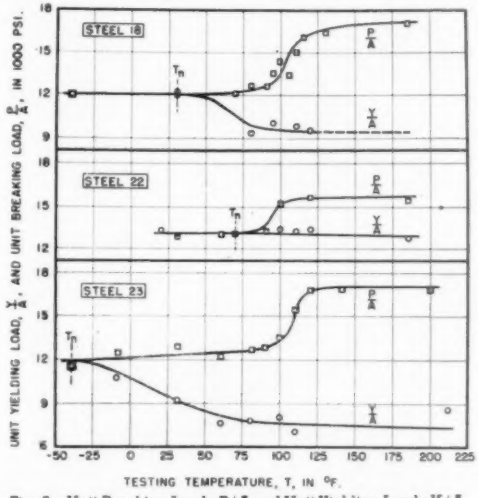


Fig. 6—Unit Breaking Loads P/A and Unit Yielding Loads Y/A, of Steels 18, 22 and 23, as a Function of the Testing Temperature. At Temperature T_a the P/A and Y/A Values Coincide with Each Other

Table 3—Determination of Transition Temperatures* by Cleavage-Tear Tests

D-Type Coupon, 45° Notch of $^3/_{16}$ in. Depth and 0.0015 in. Root Radius

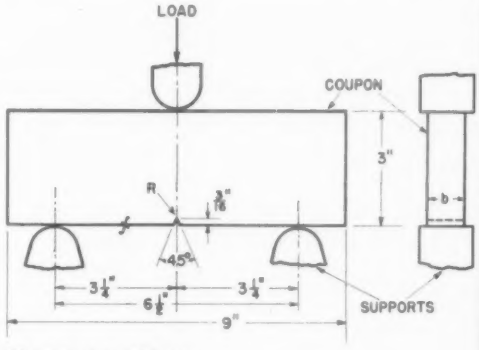
Test Temp., °F.	Unit Breaking Loads, P/A, Psi. Steel 18	Steel 22	Steel 23	Unit Yield Loads, Y/A, Psi. Steel 18	Steel 22	Steel 23
−40	12,000	...	11,600	12,000	...	11,600
−10	...	...	12,400	...	...	10,700
20	...	13,300	...	...	13,300	...
32	12,000–12,100	12,700–13,000	12,300–13,300	12,150	...	9000–9400
60	...	13,000	12,100	...	...	7600
70	11,800–12,300	12,800–13,100	...	...	...	...
80	12,600	...	12,600	9300	...	7800
90	11,800–13,300	13,200	12,600–12,700	...	...	...
95	13,500	...	...	10,000	...	...
100	12,300–16,560	15,000–15,300	12,700–14,200	...	13,300	8000
105	12,500–14,300	...	...	...	...	...
110	15,000	...	13,500–17,200	9800	13,200	7000
115	15,500–16,700	...	...	...	...	...
120	...	15,600	16,000–17,600	9500	13,300	...
130	16,400	...	...	...	...	...
140	...	...	16,000–17,600	...	...	...
186	17,100	15,300	...	...	12,700	...
200	...	...	16,700	...	...	...
212	...	...	...	...	...	8550

* Transition temperatures: Steel 18, 105° F.; Steel 22, 92° F.; Steel 23, 110° F.

for correctly evaluating the quality or serviceability of a steel.

The writer believes that for routine work the simple beam test coupon, designated DX-type and shown in Fig. 7, could be effectively utilized for evaluating the behavior of steels produced under different conditions of furnacing, deoxidation, rolling, etc. It is an extremely simple test coupon, by means of which it may be possible to determine which particular combination of manufacturing variables produces commercial steels possessing the requisite properties. It is the writer's understanding that the use of this type of test was inaugurated in a steel mill in Europe about six months ago, for testing ship-plate steels, with encouraging results. The regular impact and the tensile-impact tests could also be used as augmentary tests, if desired, even if the impact tests are of qualitative value. It has been indicated that a correlation can be established between impact and cleavage-tear and other tests if requisite data are available.[1,2]

The authors are to be congratulated for the novel approach they have used in this investigation, and for stimulating discussion on this subject.



"b" = full plate thickness.
"R" = notch root radius = 0.0015", or as specified.

Fig. 7—Simple Beam Test Coupon, DX-Type, Supported Near the Two Ends and Broken by a Single Concentrated Load Slowly Applied at Center

References

1. Bagsar, A. B., "Development of Cleavage Fractures in Mild Steels," *Trans. A.S.M.E.*, **70** (7), 751–809 (Oct. 1948). Also THE WELDING JOURNAL, **27** (3), Research Suppl., 97-s to 123-s (1948).
2. Shevandin, E. M., "Effect of Notch on Cold Brittleness of Steel," *Jnl. Tech. Phys.* (USSR), **XVII**, 1119–1136 (1947).
3. Bagsar, A. B., "Cleavage Fracturing and Transition Temperatures of Mild Steels," THE WELDING JOURNAL, **27** (3), Research Suppl., 123-s to 131-s (1948).

Authors' Closure

The contributions made by the discussors of the paper are appreciated. The range of their comments indicates the possibilities of the axial impact test in developing fundamental information regarding the properties of materials. This test is apparently not so completely phenomenological in character as the flexural or eccentric impact and static tests.

Mr. Kramer's interesting discussion implies that the differences in strain rate may be accompanied by differences in amount of precipitation, resulting in different degrees of embrittlement as the test progresses. This effect is superimposed on the general tendency of the transition temperature to decrease as the velocity of impact is lowered. The comment appears reasonable, and suggests further studies to check on its validity. However, the change in impact velocity for the different energy levels is relatively small. For 220, 110 and 45 ft.-lb. initial energy of the pendulum, the striking velocities are approximately 18, 13 and 8 ft. per second, respectively. None of the changes in transition appear to be consistent with the usual effects of velocity. However, the actual strain rates at the notch were not measured, and possibly a variation in these rates did occur with the different materials and the different initial energies.

The discussion by Mr. Klier calls attention to the lack of correlation between transition temperatures as determined from fracture appearance and from energy absorption or elongation. The same comment has been made by Dr. Bagsar. We agree with him that the energy absorption characteristics of a material are of more importance than the appearance of the fractured surface. The latter criterion, however, apparently gives curves of similar shape for all the steels. Mr. Klier does not plot

the curve for steel Dr; our results indicate a transition about 40° greater than for Dn on the basis of appearance, but both conditions of steel D showed almost the same transition by energy absorption and in the 72-in. wide plate tests.

Dr. Bagsar's objection to the small specimen used in our tests is that it does not constitute a gage to behavior of the same steel in thicker sections. He states specifically that a triaxial stress system is possible in thick sections but not in the small specimen represented in our tests. Actually, however, the low order of reduction of area for our specimens tested at low temperatures is entirely consistent with the brittle failures of Dr. Bagsar's test specimens or the wide plates at low temperatures. Our specimens apparently can be made to break with as completely brittle behavior as any other types of specimen. Confirmation of the development of triaxial stress is possible in the observation of several partial fractures obtained in our tests, in which cleavage fracture was seen to start in the center of the volume of metal in the notch.

We had two objectives in our tensile impact program: first, correlation with the wide plate tests; and second, the development of fundamental information leading to the assignment of reasons why certain steels are more susceptible to brittle failure than others. It is our opinion that Dr. Bagsar's test, along with others which have been developed, such as the Kahn tear test, may meet the first objective of correlation but the second objective is not easily possible with a specimen subjected to eccentric loading or in which compressive stress exists due to bending. We have only to look at the results of the Schnadt modification of the Charpy test specimen (to produce essentially tensile stress) to see how the deformation in compression completely changes the mode of failure and the indication of a transition temperature.

We are interested in Mr. Kies' comment that the intercept of the absorbed energy-reduction in area curves for zero ductility should have a positive value greater than the surface energy of the fracture. This intercept value (for entirely brittle fracture) can only be obtained by extrapolation. The value of the intercept, for our tests, appears to be highest for steels with low transition temperatures. There also appears to be no consistent trend in the relation of the intercept to initial energy level since the intercept values for tests at 110 ft.-lb. initial energy are a minimum for the series of tests made, as shown below.

We note Mr. Kies' opinion that significance tests applied to per cent granularity of fracture and to reduction of area data would show a higher reproducibility of the latter measurement. In our tests this would be true because it is easier to measure the latter quantity precisely.

Intercept of Absorbed Energy-Ductility Curves at 0% Ductility; Values Given in Ft.-Lb. per Square Inch

Steel	Intercept at Initial Energy of— 220 ft.-lb.	110 ft.-lb.	45 ft.-lb.	33.8 ft.-lb.
E	60	30	70	126
C	90	35	75	...
A	60	40	100	...
Dr	100	87	111	...
Dn	105	75	95	...

In answer to Mr. Irwin's comments regarding strain-aging, reference should be made to Table 12 of our paper reproduced in part from another publication of which Mr. Gensamer was co-author. The wide spread in the transition temperatures of the Charpy V- and keyhole-notch specimens is in evidence. It is also evident that the transition temperatures of the V-notch tests are higher than the transitions for the wide plates, while the transitions for the keyhole tests are considerably lower. Strain-aging was used by Gensamer, *et. al.*, purely as an artificial means of raising the transition temperatures of the keyhole type specimens in order to correspond more closely to the transition of the wide plates. Prestraining would also have an effect on the transition temperature determined from the tensile impact tests. We have included tests of prestrained and aged specimens in our research program but have no data to present at this time.

The discussion by Capt. W. P. Roop poses a number of questions and suggestions which the authors have noted. With respect to the Charpy impact test, Captain Roop says the data suggest that the Charpy test may be made more discriminating if the rate of loading is reduced. The authors also came to this conclusion; however, some pilot tests were made subsequent to the preparation of this paper. The tests were made on a few (eight) Charpy V-notch specimens of one steel at an initial energy level of 110 ft.-lb. and the results were compared with more extensive prior data for the same steel at an initial energy of 220 ft.-lb. Although the tests are too few to be conclusive, the indications were that the transition temperature was not significantly lower for the 110 ft.-lb. than for the 220 ft.-lb. initial energy level.

The comments made in the discussion of the paper have been helpful in planning the further progress of this work. To those who have contributed criticism and suggestions the authors express their thanks.

Introductory Remarks by Admiral Reed-Hill

(Continued from page 49-s)

year emphasizes the importance of the work in which the Ship Structure Committee is engaged. The problem of why welded ships fail has not been solved. Many of the unknowns, which plagued the attempts at solution which were begun at the time of the casualty to the Tanker *Schenectady*, have been evaluated, but there is, today, still no complete answer to the question.

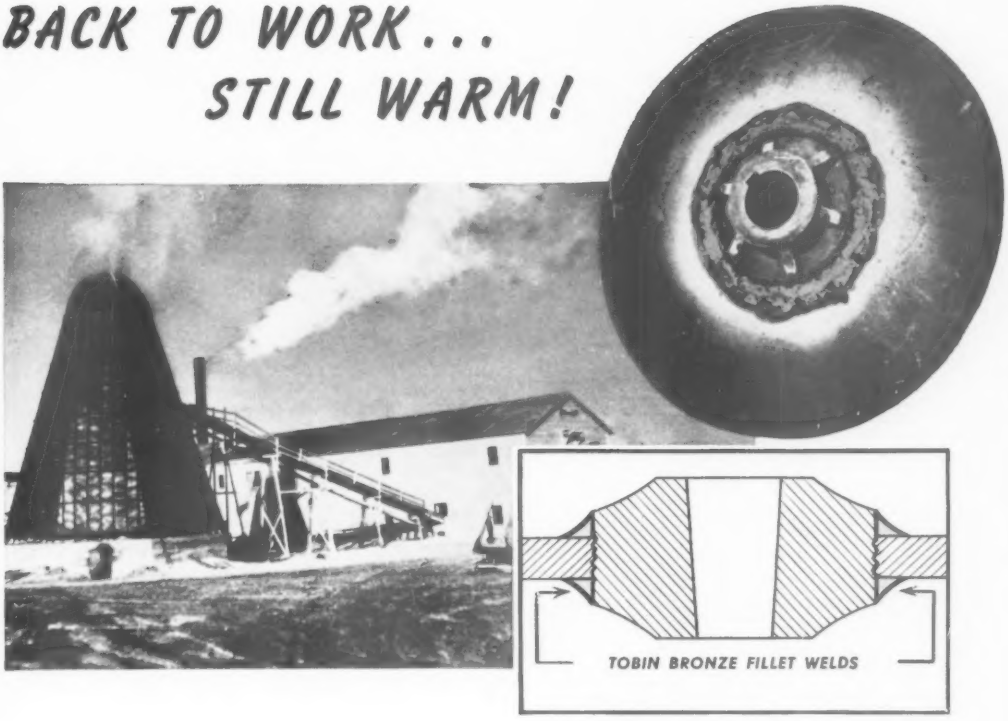
Successful ships have been built in the past and are being built today, but the design of such ships at the present time still involves some "factors of ignorance."

One of the principal objectives of the Ship Structure Committee is the substitution, for these "factors of ignorance," of a complete knowledge of the forces which a ship must resist and of the ability of the materials as fabricated to resist these forces.

It is hoped that the successful accomplishment of the work of the Ship Structure Committee will make possible the construction and operation of stronger and safer ships with decreased production costs.

The Ship Structure Committee is deeply appreciative of the efforts of the AMERICAN WELDING SOCIETY in establishing this entire day's program for a Symposium on Ship Structure Research.

BACK TO WORK... STILL WARM!



Ingenious Tobin Bronze Repair Weld cuts 10 day layoff to 7 hours downtime in Saskatchewan sawmill

FRACTURE of a vital part in the Reserve, Saskatchewan, mill of the Pas Lumber Company threatened a ten day shut-down in the height of last winter's logging season.

The 30" cast iron friction disc of the mechanism controlling the travel of the log carriage, cracked completely around its hub. The nearest spare disc was in Quebec, half a continent away.

Ernest J. Morris, welding and diesel engineer for the company, and a veteran of many crises in the wilderness, fitted the disc back on the hub, using the jagged edges of the break to locate the disc and give it accurate alignment. Since it must run true within a few thousandths of an inch and there was no lathe at hand large enough to reface the disc, the break was left untouched without veeing and the repair made with fillet welds of Tobin* Bronze and a controlled welding technique.

Seven hours after the break, the mill was operating again and 60 men saved from a layoff. Today, nearly a year later, Mr. Morris reports the unit has operated perfectly and at twice the former hours of service.

Through such emergencies as this, operators of every type of machinery are learning that "Don't scrap it, *weld* it" is good advice. For complete information on bronze welding and the fourteen different Anaconda Welding Rods now available, write for Publication B-13. 46185

*Reg. U. S. Pat. Off.

ANACONDA

Anaconda

WELDING RODS

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD.
New Toronto, Ont.

AIRCO ANNOUNCES

The Aircomatic Process... An entirely new idea for welding aluminum in ALL POSITIONS

Sensational in its conception, Airco's new *Aircomatic Process* introduces an entirely different aluminum fabricating technique to industry. With this process, welding of aluminum and weldable aluminum alloys ranging in thicknesses from ⅛" to 2" plus, may be performed in all positions – flat, horizontal, vertical and overhead. All of the standard joint designs may be welded in these positions.

Single or multi-layer welds can be deposited using either beading or weaving techniques. Vertical welds may be made with either upward or downward travel. In short, all of the facility associated with metal arc welding of steel is made available by this process, plus the advantages of high deposition rates, far exceeding those attained by usual welding methods, which results from continuous filler metal feed and the absence of slag.

This new welding method consists of feeding a bare filler metal in wire form at speeds ranging from 100 to 300 inches per minute through a manually operated gun. The filler metal carries welding current and an arc is maintained between the end of the wire and the work. Power may be supplied from a standard d.c. welding generator. The arc is maintained within a controlled envelope of shielding gas.

THE ADVANTAGES OF THIS TOTALLY UNIQUE AIRCOMATIC WELDING PROCESS INCLUDE:

- ...A manual welding process with the essential features of automatic welding.
- ...Continuous deposition of filler metal at high rates.
- ...Manual manipulation of an automatic process for welding in a vertical and overhead position.
- ...High quality weld metal deposits.
- ...Minimum edge preparation owing to deep penetration.
- ...Ability to weld heavy sections with little or no preheat.
- ...No flux required; slag removal eliminated.
- ...Visible arc; no blind welding.

Investigate the many advantages the new Aircomatic Welding Process *offers you. For equipment, price, service or other pertinent information, call or write our nearest office.*

AIRCO **AIR REDUCTION**

Offices in Principal Cities

Headquarters for Oxygen, Acetylene and Other Gases . . . Carbide . . . Gas Welding and Cutting Machines, Apparatus and Supplies . . . Arc Welders, Electrodes and Accessories